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MATHEMATICS BEFORE THE GREEKS[1]

By Professor R. C. ARCHIBALD

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OUR conceptions of Egyptian and Babylonian mathematics have been notably changed during the past fifteen years so that the third edition of the first volume of Cantor's great history is already quite out of date. Even since last March much of great interest to the student has been published. Hence it seemed both appropriate and timely for me to endeavor to present to you an accurate even though fragmentary survey of present knowledge of the mathematics of the Egyptians and Babylonians, for it is to theirs alone that I shall refer in considering mathematics before the Greeks, that is, before 600 B. C. Indeed, practically all the mathematics which I shall consider was in use before 1600 B. C.

For at least a thousand years prior to 2500 B. C. the non-Semitic Sumerians, who lived just north of the Persian Gulf and south of the Semitic Akkadians, were generally predominant in Babylonia, but were absorbed in a larger political group by about 2000 B. C. One of the greatest of the Sumerian inventions was the adoption of cuneiform script; notable engineering works of the Babylonians, by means of which marshes were drained and the overflow of the rivers regulated by canals, went back to Sumerian times, like also a considerable part of their religion and law, and their system of mathematics, except, possibly, for certain details.

Our knowledge of Babylonian mathematics is derived mainly from tablets in the British Museum, the Prussian State Museum of Berlin, the Ottoman Museum of Constantinople, the University of Strasbourg, the University of Pennsylvania and the Palais du Cinquantenaire of Brussels. Nearly thirty years ago about forty-seven mathematical problems were published in important part IX of "Cuneiform Texts

[1] Retiring address, as vice-president and chairman of Section A—Mathematics, of the American Association for the Advancement of Science, delivered at Des Moines, Iowa, December 30, 1929.

from Babylonian Tablets, etc., in the British Museum" (we shall later refer to this as *CT*.IX), but so far as published material is concerned very little headway has been made in interpreting the problems.

Our knowledge of Egyptian mathematics is gleaned chiefly from two papyri. One of these, called the Rhind papyrus, was written about 1650 B. C., but is a copy of a document which possibly dates back to 1850 B. C., and is preserved in the British Museum, except for some fragments in New York City. Three editions of this have been published: the first by A. Eisenlohr in 1877; the second by T. E. Peet in 1923, and the third by A. B. Chace, L. S. Bull and H. P. Manning in 1927–29. The last-named work contains also my survey of the literature of Egyptian and Babylonian mathematics during the past 225 years.[2] The second mathematical papyrus, called the Golenishchev Papyrus, is in the Museum of Fine Arts in Moscow and was written about 1850 B. C.; but it, too, may be a copy of an older writing of about 2000 B. C. Only five of its twenty-five problems have been published, but through the great courtesy and generosity of a Russian colleague, Professor V. V. Struve, of the Hermitage Museum in Leningrad, I have been furnished with detailed information concerning the re-remaining problems of the papyrus.

The earliest dated event in history was the establishment in 4241 B. C. of the Egyptian calendar[3] of twelve months of thirty days each plus five feast days. This action implies a certain use of mathematics at this distant date. Another indication of the primitive development of Egyptian civilization is that writing was in use as early as 3500 B. C., and indeed at this date we find that the Egyptians were already in possession of the decimal system of notation. This is proved by an inscription on a great Hierakonopolis royal mace[4] now to be seen at Oxford. The inscription contains a reference to 120,000 captives and a register of captive animals, 400,000 oxen and 1,422,000 goats. In hieroglyphic writing unity is denoted by a stroke; 10 by an inverted capital U or handle; 100 by a curved rope; 1,000 by a lotus flower, very common in Egyptian fields; 10,000 by an upright bent finger; 100,000 by a tadpole, and 1,000,000 by a god with uplifted hands. Therefore 1,234,567 would be written: a god, then two tadpoles, followed by three bent fingers, followed by four lotus flowers, followed by five ropes, followed by six handles, followed by seven strokes. Such was the writing of large numbers in 3500 B. C. How much earlier was the real beginning of Egyptian mathematics? Did Egyptian and Babylonian mathematics have a common source, or were they independent in origin? It seems as if all that we can at present state with certainty is that by 2000 B. C. we find these two separate highly developed systems, that in the case of one of them a notable stage had been reached 1500 years earlier and that in the case of the other by 2400 B. C., at least, marked development had occurred.

Sumerian mathematics was essentially sexagesimal and while a special symbol for 10 was constantly used it occupied a subordinate position; there were no symbols for 100 or 1,000. One hundred was regarded as $60+40$, 1,000 as $16.60+40$, but in this latter case the Sumerian would simply write 16.40. So also 31.6.15 might equal 111,975. In other words, the Sumerians had a positional notation for their numbers. Their symbol for unity was also the symbol for 60, 60^2, for 60^3, etc., or for 60^{-1}, 60^{-2}, etc. Thus 31.6.15 might mean not only 111,975 but also 6,718,500, or 1866 1/4, or 31 1/10 1/240. When the unit for the first number to the right was known, the whole was determined. The uncertainty in this regard is one of the great difficulties in interpreting Babylonian mathematical texts. Within the period we are considering there was no symbol for zero but a blank space was left,[5] so that 10. .7 might stand for 36,007. In this way another element of uncertainty was introduced in interpreting these ancient writings.

While the largest fractional unit was 60^{-1}, ten of these units gave 1/6 and in ordinary calculations this occupied a central position. In early calculations there were also signs for $1/3(=2/6)$; $1/2(=3/6)$ and $2/3$ $(=4/6)$, and by about 2200 B. C. there were also signs for 5/6, 1/5, 1/4. So far as our knowledge goes the Babylonians never used such complicated fractions as the Egyptians readily handled.

Babylonian multiplication tables are very numerous and are almost always the products of a certain number successively by 1, 2, 3 . . . 20, then 30, 40 and 50. For example, on tablets of about 1500 B. C. at Brussels[6] are tables of 7, 10, 12½, 16, 24, each mul-

[2] In the course of the following foot-notes "Bibliography" will refer to this survey.

[3] J. H. Breasted, "Ancient Times," Boston, 1916, p. 45.

[4] J. E. Quibell, "Hierakonopolis," pt. 1, London, 1900, plate 26B.

[5] The sign replacing the blanks seems to have been first used about 250 B. C.; see the copy of a British Museum tablet in F. X. Kugler, "Die Babylonische Mondrechnung," Freiburg-i-B., 1900, plate 5, l. 26, sign, 3, l. 88, sign 3, l. 89, sign 8, etc.

[6] L. Speleers, "Recueil des Inscriptions de l'Asie Antérieure des Musées Royaux du Cinquantenaire à Bruxelles," Brussels, 1925, p. 29, 94–95. In the University of Pennsylvania there are twenty-three tablets containing multiplication tables, in part or complete, and dated for the most part about 1300 B. C.; but a few are dated 2000 B. C. The multipliers are such numbers as: 2, 6, 9, 18, 30, 36, 90, 432, 450, 540, 960, 1080, 2160; see H. V. Hilprecht, "Mathematical, Metrological and Chronological Tablets," Philadelphia, 1906, p. 57–61, 68–69. See also British Museum, "A Guide to the Babylonian and Assyrian Antiquities," third ed., London, 1922, p. 161.

tiplied into such a series of numbers. There are various tablets giving the squares of numbers[7] from 1 to 50, and also the cubes, square roots and cube roots of numbers. But we must be careful not to assume too much from this statement; the tables of square roots and cube roots were really exactly the same as tables of squares and cubes, but differently expressed.[8] In the period we are considering the Egyptian really had nothing to correspond to any of these tables, nor do we know that even the conception of cube root was within his ken. There are also tablets exhibiting the process of division: 60 by its integral factors[9] and 12,960,000 (according to one interpretation) by some of its factors.[10] In connection with one of these latter tablets we find two series of numbers in geometric progression 125, 250 . . . , 16,000; 810, 1620 . . . , 103,680. We shall later refer to another series of numbers in geometric progression 5, 10 . . . , 80 found in an Akkadian tablet of the seventh century B. C. Sumerian multiplication tables would, of course, give numbers in arithmetic progression.

But turning from such tables to arithmetic calling for their application we find that long before coins were in use the custom of paying interest for the loan of produce, or of a certain weight of a precious metal, was common. Sumerian tablets indicate that the rate of interest varied from 20 per cent. to 30 per cent., the higher rate being charged for produce. At a later period the rate was 5½ per cent. to 25 per cent. for metal and 20 per cent. to 33⅓ per cent. for produce.[11] An extraordinary number of tablets show that the Sumerian merchant of 2500 B. C. was familiar with such things as weights and measures, bills, receipts, notes and accounts.

The study of the weights and measures of the Babylonians seems especially important for clearly understanding their mathematics, as Neugebauer, building on work of Thureau-Dangin and others, has recently argued.[12] But time will not permit me to discuss this topic or the large subject of the metrology of the Egyptians.[13]

Let us now consider some characteristics of Egyptian mathematics. We have remarked that tables such as a Babylonian used were not part of an Egyptian's equipment. He did use other tables, however, which dealt with the fundamental feature of his arithmetic, namely, the expression in terms of two or more unit fractions of (*a*) one unit fraction,[14] *e.g.*, 1/7 = 1/14 1/21 1/42; (*b*) 2 divided by an odd number,[15] and (*c*) other quotients,[16] as 3 ÷ 10 = 1/5 1/10; for, with the single exception[17] of 2/3, the Egyptian had no notation for other fractions. After the title page of the Rhind papyrus, more than a quarter of the written part of the papyrus is occupied with a table expressing in this way 2 divided by the various odd numbers 5 to 101 inclusive. For example, 2 : 7 = 1/4 + 1/28,

[7] For example, in the University of Pennsylvania, dating from about 1300 B. C.; see Hilprecht, "Mathematical, Metrological and Chronological Tablets," Philadelphia, 1906, p. 69, and plate X. See also British Museum, "A Guide to the Babylonian and Assyrian Antiquities," third ed., London, 1922, p. 161.

[8] The two tablets with square roots in the University of Pennsylvania date from about 2000 B. C.; see Hilprecht, *ibid*, p. 62–63, and pl. 16. A tablet in the British Museum dating from about 1900 B. C. and containing tables of square roots and cube roots is described in F. Lenormant, "Essai sur un document mathématique chaldéen," Paris, 1868 (for further references in this connection see my Bibliography). For a tablet with squares, cubes, etc., of a given number see British Museum, "A Guide to the Babylonian . . . ," 1922, p. 161. See also M. Cantor, "Babylonische Quadratwurzeln und Kubikwurzeln," *Zeitschrift für Assyriologie*, 21: 110–115, 1908.

To illustrate arithmetical operations of about 2000 B. C. a quotation may be made from a problem on a tablet transcribed by C. Frank, "Strassburger Keilschrifttexte in sumerischer und babylonischer Sprache," *Schriften der Strassburger Wissenschaftlichen Gesellschaft in Heidelberg*, n.s., Berlin, 1928, Heft 9, p. 21: " . . . the square of 13.20 is 2.57.46.40. Add 2.57.46.40 to 50.33.20. It is 53.31.6.40. The square root of 53.31.6.40 is 56.40."

[9] A Tello tablet of about 2200 B. C. in Constantinople; no. M. I. O. 7375 in vol. 3 of "Inventaire des tablettes de Tello." (See also L. Delaporte, *Revue d'Assyriologie*, 8: 131–133, 1911.)

[10] Four tablets of about 2000 B. C. in the University of Pennsylvania; see Hilprecht, "Mathematical . . . ," p. 61–62, pls. 10, 12, 14, 15. While the tablets exhibit divisions, it is not certain that the dividend is 12,960,000, which Hilprecht called the geometric number of Plato. The literature of this topic is extensive. See, for example, A. G. Laird, "Plato's Geometric Number and the Comment of Proclus," Madison, 1918.

[11] M. Jastrow, Jr., "The Civilization of Babylonia and Assyria," Philadelphia, 1915, p. 326, 338; C. H. W. Johns, "Babylonian and Assyrian Laws, Contracts and Letters," New York, 1904, p. 251, 255–256. See also D. E. Smith, "History of Mathematics." vol. 2, 1925, p. 560.

[12] O. Neugebauer, "Zur Entstehung des Sexigesimalsystems," Gesellschaft der Wissenschaften zu Göttingen, *Abhandlungen- math.-phys. Klasse*, n.s. vol. 13, no. 1, 1927; Thureau-Dangin, Numération et métrologie sumeriennes," *Revue d'Assyriologie*, 18: 123–142, 1921.

[13] A source of fundamental importance is F. L. Griffith, "Notes on Egyptian Weights and Measures," Society of Bibl. Archaeology, *Proceedings*, 14: 403–450, 1892; 15: 301–315, 1893.

[14] For example in a document of about 1650 B. C., Leather roll, B.M. 10250, *Journal of Egyptian Archaeology*, 13: p. 232–238, 1927, + plates; article by S. R. K. Glanville.

[15] As in the Rhind Papyrus of about 1650 B. C.

[16] See, for example, the table of the divisions of the numbers 1–9 by 10 in the Rhind papyrus; for a table 2000 years later see H. Thompson, "A Byzantine Table of Fractions," *Ancient Egypt*, 1914, p. 52–54.

[17] Compare K. Sethe, "Von Zahlen und Zahlworten bei den alten Ägyptern," (*Schriften der wissenschaftlichen Gesellschaft in Strassburg*, Heft 25), Strasbourg, 1916; it is here made clear (p. 94) that the sign for 2/3 did not, at least in its original form, suggest that 2/3 was thought of as 1/1½.

$2 \div 97 = 1/56 + 1/679 + 1/776$, and both of these results as well as $2/3 = 1/2 + 1/6$ are used in the course of the solution of the thirty-first, of about eighty problems[18] of the papyrus following the table. In these illustrations from the table, 2 divided by an odd number is expressed in terms of the sum of either two or three unit fractions. But four unit fractions are given in eight of the forty-nine divisions. The last of these, $2 \div 101 = 1/101 + 1/202 + 1/303 + 1/606$, is interesting for two reasons: (1) because we first learned of it in 1923 through papyrus fragments discovered in New York City, and (2) because this is the *only* case of this table where a unit fraction has the same denominator as that of the fraction being resolved. All sorts of conjectures have been made, and theories formulated, as to how the author of the papyrus came to select out of the infinite number of possibilities in this table the particular sets given. These discussions include a very elaborate monograph and two doctoral dissertations, one of them appearing less than two months ago at the University of Munich and containing nearly 220 pages.[19]

The form of this table of 2 divided by an odd number is often merely a verification by multiplication and addition of the result stated. For example, in connection with the relation already referred to $2 \div 97 = 1/56 + 1/679 + 1/776$, 97 is multiplied by 1/56 to give 1 1/2 1/8 1/14 1/28; 1/679 of 97 is 1/7; 1/776 of 97 is 1/8. The sum of these products or quotients is 2 as it should be. Now how did the Egyptian arrive at these results? In the case of 1/776 of 97 he would consider what number multiplied by 97 gives 776 and he would multiply 97 successively by 2 thus:

1	97
2	194
4	388
\8	776

from which it follows that the $97 \div 776 = 1/8$. So also for $97 \div 679$; for on adding 4 and 2 and 1 times 97, we find that 7 times 97 gives 679. In the case of $97 \div 56$ the Egyptian would inquire what was the result of taking 1/56 of 97; we may proceed by inquiring what number we would multiply 56 by in order to get 97. The work would be as follows:

\1	56
\1/2	28
1/4	14
\1/8	7
\1/14	4
\1/28	2

from which we see that the multiplier of 56 which gives 97 is 1 1/2 1/8 1/14 1/28. (The check marks which I have used were employed in exactly the same way by the Egyptian.) Let us consider one other example to illustrate further points in multiplication. Suppose the Egyptian were asked to find what parts of 105 loaves will make 82 he might seek multipliers of 105 to give[20] 82. Thus:

1	105
\2/3	70
1/3	35
1/30	3½
\1/15	7
1/10	10½
1/5	21
\1/21	5

Total 2/3 1/15 1/21

To sum up, problems of division are reduced to those of multiplication; multiplication of two numbers is carried through by successive multiplications of one of the numbers by twos or tens or by 2/3, or by divisions of the number by twos or tens. The further extraordinary fact is revealed that in order to get 1/3 of any number, the Egyptian frequently first found the value of 2/3 of the number, and then halved the result. This is illustrated repeatedly in the Rhind papyrus.[21] It would seem as if the Egyptian had specialized in the technique of taking $1/1\frac{1}{2}$ of any number,[22] or used tables for this purpose.[23]

There are only two general rules in the Rhind papyrus; one of these is in problem 61 for finding 2/3 of the reciprocal of an odd number. The rule is as follows: "To get 2/3 of 1/5 take the reciprocals of 2 times 5, and 6 times 5; and in the same way get 2/3 of the reciprocal of any odd number." This rule is

[18] For convenience in reference Eisenlohr introduced nos. 1–87 for referring to different parts of the Rhind papyrus, just as Struve uses nos. 1–25 for the Golenishchev papyrus. But numbers 85–87, and some of the others, are not problems.

[19] See Lepsius (1865), Loria (1892), Bobynin (1890, 1899), Cantor (1880), Mansion (1888), Hultsch (1895, 1901), Neugebauer (1926), Gillain (1927, 1928), Vogel (1929), and other references in my Bibliography.

[20] Compare problems 21 and 22 of the Rhind papyrus.

[21] For example, problems 8, 16–20, 25, 29, 32, 38, 42, 43, and 67. See the Chace edition of the Rhind papyrus, vol. I, p. 4, where Gunn's view to the contrary is refuted.

[22] That $1/1\frac{1}{2}$ of a number is equivalent to 2/3 of that number is illustrated in problem 33. So also in problem 19 of the Golenishchev papyrus; but possibly this last reference may be quoted in support of Gunn's view that to get 2/3 of a number, 1/3 of that number was first found.

[23] It seems probable that such a table was given in a Byzantine table of fractions studied by Thompson, *Ancient Egypt*, 1914; see K. Sethe, "Von Zahlen und Zahlworten bei den alten Ägypten," Strasbourg, 1916, p. 70.

applied several times[24] in the papyrus; the remarkable application in problem 33 gives 2/3 of 1/679 = 1/1358 1/4074.

The second general rule is indicated in connection with problem 66: "If 10 hekat of fat are given out for a year, what is the amount used in a day?" The year is taken as containing 365 days and since there are 320 ro in one hekat, the problem is reduced to finding how many times 365 is contained in 3200 and the answer is found to be 8 2/3 1/10 1/2190 ro. The general rule then follows: "Do the same thing in any example like this."[25]

To illustrate other interesting points let us consider problem 33 of the Rhind papyrus: "A quantity, its 2/3, its 1/2 and its 1/7 added together become 37. What is the quantity?"[26] We would now naturally solve this as a simple equation in algebra $x(1+2/3+1/2+1/7)=37$ and find $x=16\ 2/97$. The Egyptian asked himself what number multiplied into 1 2/3 1/2 1/7 gives 37. By manipulation illustrated above, he soon finds that $16(1+2/3+1/2+1/7)=36\ 2/3\ 1/4\ 1/28$ which is less than the 37 he wants by an amount which he proceeds to determine in using 42 as a comparison number. Taking 2/3 1/4 1/28 of 42, he gets 40 there remains 2; in other words 2/3 1/4 1/28 differs from 1, which was necessary to add to 36 in order to give 37, by 1/21. The author then shows that 1 2/3 1/2 1/7 applied to 42 gives 97 and hence knows that 1/97 of 1 2/3 1/2 1/7 is 1/42; whence, multiplying this result by 2, he gets $2 \div 97$ or 1/56 1/679 1/776 of 1 2/3 1/2 1/7 is equal to 1/21. Hence he has as answer 16 1/56 1/679 1/776.

By my method of presentation I have tried to indicate that in use of a comparison number 42 the Egyptian did not necessarily think of fractions other than unit fractions, although we might say that his operation was *equivalent to* bringing to a common denominator. The question comes up again in vastly more complicated form when he proves that the result he has got is correct. After writing down the products

1	16 1/56 1/679 1/776
2/3	10 2/3 1/84 1/1358 1/4074 1/1164
1/2	8 1/112 1/1358 1/1552
1/7	2 1/4 1/28 1/392 1/4753 1/5432

he proceeds to prove that the sum of his products is 37 and makes use of the comparison number 5432.

The question as to whether the Egyptian had a *conception* of the general fraction has been the topic of much discussion. Sethe believed that he did not;[27] but Peet[28] and Wieleitner[29] hold to a contrary view. By excessively brief suggestion I have attempted to present the somewhat original view set forth in the Chace edition of the Rhind papyrus.

One is tempted to dwell on some other Egyptian problems which we might solve by simultaneous equations. Turning to the Rhind papyrus, we may consider problem 40, which we would naturally solve with two linear simultaneous equations. The problem is as follows: "Divide 100 loaves among 5 men in such a way that the shares received shall be in arithmetical progression and that 1/7 of the sum of the largest three shares shall be equal to the sum of the smallest two. What are the shares?" The solution starts in at once: "Do it thus: Make the difference of the shares 5 1/2. Then the amounts the five men receive will be 23 17½ 12 6½ 1, total 60. As many times as it is necessary to multiply 60 to make 100, so many times must these terms be multiplied to make the true series, and it is found that 1 2/3 times 60 make 100 and hence the shares 38 1/3, 29 1/6, 20, 10 2/3, 1 2/3. The use of proportion here is especially interesting.[30] For the very attractive method by which the Egyptian probably arrived at the difference 5 1/2 on assuming that one man's share was 1, see Chace's edition of the papyrus. The problem is notable also as illustrating that while the Egyptian did not consider such things as simultaneous equations, he was nevertheless able in certain cases to obtain the result by methods at his command.

Problem 64 is another one involving an arithmetic progression[31]: "Distribute 10 hekat of barley among 10 men in such a way that the shares shall be in arithmetical progression with a common difference of 1/8 hekat. What is the share of each?"[32]

Problem 79 seems to be as follows: "In each of 7 houses are 7 cats, each cat kills 7 mice, each mouse would have eaten 7 ears of spelt, each ear of spelt will produce 7 hekat of grain; how much grain is thereby saved?" But the author gives only the sum of the five terms of the geometric progression of which the first term is 7 and the multiplier 7. The

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[24] Rhind Papyrus, problems 17, 30, 33, 61.

[25] Compare the Latin, "*Fac ita,*" and the early German, "*Thu ihm also.*"

[26] This problem is exactly the same as problem 31, if 33 is substituted for 37.

[27] K. Sethe, (*a*) "Von Zahlen und Zahlworten bei den alten Ägyptern," Strasbourg, 1916, p. 62; (*b*) "Deutsche Mathematiker-Vereinigung," *Jahresbericht*, 33: 141, 1925.

[28] T. E. Peet, "Rhind Papyrus," p. 16–17.

[29] H. Wieleitner, "Kannten die Ägypter den Begriff eines allgemeien Bruches?" *Mitteilungen zur Geschichte der Medizin und der Naturwissenschaften*, 25: 1–4, 1926.

[30] Problem no. 7 of the Golenishchev papyrus contains a special word for ratio; compare Peet, p. 60.

[31] A third Egyptian problem involving an arithmetic progression is in the Kahun Papyri of about 1850 B. C.; see F. L. Griffith, "The Petrie Papyri. Hieratic Papyri from Kahun," 2 vols., London, 1897–98 (see Bibliography).

[32] I have given a new solution of this problem in *Isis*, December, 1928, 11: p. 397 (in line 12 of this page *for* "shares 3" *read* "share,").

proof which he gives has been the subject of speculation as to whether the Egyptian knew of a certain general relation in connection with geometric series; but it has recently become clear[33] that nothing but multiplication is here involved. The problem is of interest from another point of view. In a thirteenth century work of Leonardo of Pisa the following problem occurs[34]: "7 old women invaded Rome; each woman had 7 donkeys; each donkey carried 7 sacks; each sack contained 7 loaves of bread; with each loaf were 7 knives; each knife was in 7 sheaths? What is the total?" The persistence of this type of problem after twenty-eight centuries is notable. Even in our own day we have: "As I was going to St. Ives I met a man with 7 wives; each wife had 7 sacks; each sack had 7 cats; each cat had 7 kits; kits, cats, sacks and wives, how many were there going to St. Ives?"

No sketch of Egyptian mathematics should fail to refer to the process of false position which was so freely used[35] and which has been employed through the centuries even down to our arithmetics of a generation ago. The method consists in assuming a certain numerical answer and then, by performing the operations of the problem, arriving at a number, which can be compared with a given number, the true answer having the same relation to the assumed answer that the given number has to the number thus obtained. Consider an example. In problem 27 it is required to find a quantity such that it and its 1/5 added together become 21. In the solution 5 is assumed for the quantity then the quantity and its 1/5 make 6. As many times as 6 must be multiplied to give 21, so many times must 5 be multiplied to give the required number. It is found that 6 had to be multiplied by $3\frac{1}{2}$; hence the required number is 5 multiplied by $3\frac{1}{2}$ or $17\frac{1}{2}$.

In concluding these references to various arithmetic operations and processes it should be noted that the idea of squaring a quantity was not unknown to the Egyptian. This is indicated by its use in problems 11 and 14 of the Golenishchev papyrus. So also for the square root of a number, for which a special sign is used in problems 6, 7 and 17 of the Golenishchev papyrus, in one of the Kahun papyri,[36] and in Berlin papyrus 6619,[37] all three dating from about 1850 B. C. The square roots of integers are found in all but the two examples of the Berlin papyrus, where the square roots of 6 1/4 and of 1 1/2 1/16 are given.

But there are other problems not so interesting for their mathematics as for other things. For example, problem 67 of the Rhind papyrus starts out in this way: "The herdsman came to the stock-taking with 70 cattle. The accountant said to the herdsman, Very few tribute-cattle art thou bringing; pray where are all thy tribute cattle? The herdsman replied to him, What I have brought is 2/3 of 1/3 of the cattle that thou hast committed to my care. Count and thou wilt find the full number." In this way it appears that 70 out of 315 cattle were levied by the owner as tribute.

Problem 62 is as follows: "Example of reckoning the contents of a bag of various precious metals. Suppose it is said to thee, A bag containing equal weights of gold, silver and lead has been bought for 84 rings. What is the amount in it of each precious metal, that which is given for a deben of gold being 12 rings, for a deben of silver 6 rings and for a deben of lead 3 rings?"

The feed for geese, cranes, ducks, quails, doves, also for bulls and common cattle, is discussed in problems 82–84. In the Golenishchev papyrus is the following rule-of-three: Problem 23: "A sandal maker works for 15 days receiving wages every five days. If he does the work in 10 days after what periods should he be paid?"

Then, too, 10 of the 25 problems in the Golenishchev[38] and 10 of about 80 in the Rhind[39] papyrus are so-called pefsu, or cooking ratio, problems. Pefsu is the number of units of food or drink that could be made from a unit of material in the process of cooking, and it determined the relative value of any food or drink; the lower the pefsu, the more valuable the unit of food. A couple of enunciations only may be given in illustration: (*a*) Rhind, no. 69, "$3\frac{1}{2}$ hekat of meal are made into 80 loaves of bread. Let me know the amount of meal in each loaf and what is the pefsu." (*b*) Rhind, 78, "Suppose it is said to thee, 100 loaves of pefsu 10 are to be exchanged for a quantity of beer of pefsu 2. How many des of beer will there be?"

Any survey of the mathematics of the Egyptians ought to include at least a brief reference to one of their extraordinary monuments, the great pyramid at Gizeh, erected during the reign of Cheops about 2900 B. C. The mere fact that the erection of such a structure was possible indicates a very remarkable governmental and social organization. It is said that 100,000 workmen were kept constantly employed on this structure for fifty years, ten years of this period being used in constructing a road to the limestone quarry some miles distant. It has been estimated

[33] O. Neugebauer, "Die Grundlagen der ägyptischen Bruchrechnung," Berlin, 1926, p. 14–15.

[34] Leonardo of Pisa, "Scritti," vol. 1, Rome, 1857, p. 311–312.

[35] For example in problems 24–27, 35, 37, 38 of the Rhind papyrus; also in 40 which we have already discussed.

[36] F. L. Griffith, "The Petrie Papyri. Hieratic Papyri from Kahun and Gurob," vol. 2, plate VIII.

[37] H. Schack-Schackenburg, *Zeitschrift für ägyptische Sprache*, 38: 138, 1900; 39: 65, 1901.

[38] Nos. 5, 8, 9, 12, 13, 15, 16, 20, 22, and 24.

[39] Nos. 69–78.

that over this road were brought 2,300,000 blocks of stone averaging two and one half tons in weight. These blocks were fitted together very perfectly. For the roofs of chambers granite blocks twenty-seven feet long, six feet high and four feet thick, and weighing some fifty-four tons each, were brought from the quarry over 600 miles away and conveyed by a brick ramp to their position over 200 feet above the ground level. The pyramid covered about thirteen acres and recent surveys show[40] that its base was almost a perfect square, no side differing from the mean length of 755.78 feet by more than 4½ inches, while two of its angles differ from 90° by less than 34 seconds, and the other two by less than 3½ minutes.[41] The orientation of a side of the square being almost exactly north and south was an indication not only of careful observations of the stars by the Egyptians but also of astrological considerations, so prevalent in those days. The height of the pyramid was about 481 feet, and there were various passage ways to the chambers within the structure. Especially since the publications of John Taylor in 1859 and 1864, and of C. Piazzi Smyth, astronomer royal for Scotland, in 1864 and 1867, even down to 1929, all sorts of curious pyramid mysticism has been the subject of discussion in scores of chapters, articles, pamphlets and books.[42] In connection with the pyramid of Gizeh such mysticism has led to conclusions like the following being regarded as gospel: (1) it was built in the present proportions so that the perimeter of its base should be exactly equal to the perimeter of a circle of which the pyramid's height was radius; (2) the perimeter of the base was so chosen that it might contain one hundred times as many pyramid inches as there are days in the year; (3) the pyramid inch is equal to a five hundred millionth part of the earth's polar diameter; (4) the total area is divided in golden section, that is, the area of the base is to the sum of the areas of the faces as this sum is to the sum of the areas of the faces and base; (5) it was intentionally placed exactly in latitude 30°.

Had De Morgan lived a few years longer his recreation of crushing circle-squarers might well have been set aside for plaguing pyramiders.

But the problems of mechanics and engineering involved in handling even the larger stone blocks of the pyramids were slight as compared with those dealt with by Egyptians in quarrying and setting up some of their huge obelisks[43] of pink granite. The largest existing obelisk, quarried about 1500 B. C., was no less than 105 feet long, nearly ten feet square at the larger end and about 430 tons in weight. It was set up in front of the Temple of the Sun at Thebes, but moved, about 1,800 years later, to the piazza of St. John Lateran at Rome, where it may be seen to-day.

But another extraordinary fact to be noted, concerning the engineers or surveyors contemporary with the pyramid and obelisk builders, is that they were already in possession of methods for laying out nilometers around innumerable bends in the river Nile for a distance of seven hundred miles such that the zero points of the nilometers, always below lowest water, are all in one plane.[44]

Let us now turn from applied to results which we usually associate with pure mathematics and consider the geometry of the Babylonians and Egyptians.

Babylonian Geometry

One of the most interesting of Babylonian tablets was found at Tello, Arabia, and is now in the Ottoman Museum at Constantinople. It dates back to about 2200 B. C. and was first described in 1896 by Eisenlohr[45] and Oppert,[46] and later by Thureau-Dangin.[47] It is the plan of a great field divided into 15 parts: 7 right triangles, 4 rectangles (nearly) and 4 trapezia[48] (one side always perpendicular to the parallel sides). The lengths of the lines and the areas of the parts which are indicated show that the following geometrical results, probably derived wholly empirically, were known at that time:

1. The area of a rectangle is the product of the lengths of two adjacent sides.

2. The area of a right triangle is equal to one half the product of the lengths of the sides about the right angle.

3. The area of a trapezium with one side perpendicular to the parallel sides is one half the product of the

[40] I. H. Cole, "Determination of the Exact Size and Orientation of the Great Pyramid of Giza," Survey of Egypt, Paper no. 39, Cairo, 1925; L. Borchardt, "Längen und Richtungen der vier Grundkanten der grossen Pyramide bei Gise," Berlin, 1926.

[41] The results quoted by J. H. Breasted in this connection (*Scientific Monthly*, 10: 92, 1920) have since been found to be incorrect.

[42] Particularly under 1854, 1910, and 1928 (Suppl) in my Bibliography are some sample titles in this field. See also Borchardt's pamphlet listed under 1922.

[43] A recent valuable work devoting considerable space to the mechanics of setting up obelisks is "The Problem of the Obelisks from a Study of the Unfinished Obelisk at Aswan," London, 1923, by R. Engelbach, an Englishman who is director of the Egyptian Museum at Cairo.

[44] J. H. Breasted, *Scientific Monthly*, 10: 91, 1920. See also L. Borchardt, "Nilmesser und Nilstandsmarken," Berlin, 1906 (in Preuss. Akad. d. Wissenschaften, *Abhandlungen*).

[45] A. Eisenlohr, *Ein altbabylonischer Feldplan*, Leipzig, 1896.

[46] J. Oppert, Académie d. Inscriptions et Belles-Lettres, *Comptes Rendus*, s. 4, v. 24, 1896, p. 331–348; also in *Revue d'Assyriologie et d'Archéologie Orientale*, v. 4, 1897, p. 28–33.

[47] F. Thureau-Dangin, *Revue d'Assyriologie*, v. 4, 1897, p. 13–27.

[48] The meaning of the terms "trapezium" and "trapezia" of this paper is that used in every country of the world except the United States.

length of this perpendicular and the sum of the lengths of the parallel sides.

For the history of the Pythagorean theorem a portion of an Akkadean tablet in the Prussian State Museum, dating back to about 2000 B. C., is of special interest. It was published by Weidner[49] in 1916. The figure of a rectangle with one diagonal is drawn and the dimensions of the rectangle, 10, "breadth," and 40, "height," are given. Two methods are used to calculate the length c of the diagonal. The first method leads in numbers to the approximation $c = a + 2ab^2.60^{-2}$, where a is the length of the greater side and b of the lesser. The text of the solution here translated freely is as follows:

Square the side of length 10 then thou will get $1 \cdot 40$ $[60 + 40 = 100]$. The square area 1.40 [100] multiplied by the length 40 of the other side gives thee 1.6.40 $[1 \cdot 60^2 + 6 \cdot 60 + 40 = 4000]$. In doubling thou wilt get 2.13.20 $[2 \times 62^2 + 13 \cdot 20 = 8000]$ adding that to 40 thou wilt get 42.13.20 $[42 + 13 \cdot 60^{-1} + 20 \cdot 60^{-2}]$ as diagonal. Such is the calculation.

The second method seems to lead in numbers to the relation $c = a + b^2/2a$ which is what one arrives at in the calculation of $(a^2 + b^2)^{1/2}$ if terms after the second are neglected. The result found here is $41 + 15.60^{-1}$. How were the Akkadians led to such formulas? It is not possible to believe that in the case of the second approximation they thought of anything like a binomial expansion which we find natural, even though Hilprecht be correct in thinking that they were familiar with the expansion[50] $(a+b)^2 = a^2 + 2ab + b^2$. Rather are such approximations remarkable developments to meet needs, as we observe in other directions, in connection with these extraordinary people.

This tablet suggests that the Babylonians may have known the Pythagorean theorem for a right triangle. This appears to be a certainty when we consider two among forty-seven mathematical problems in *CT*.IX. It was less than nine months ago, in a paper by Struve and Neugebauer,[51] that the meaning of these two problems became clear. In the first of these problems we are given the length 60 of the circumference of a circle and the length 2 of a perpendicular from the center of a chord of the circle to the circumference; it is required to find the length of the chord. If d denotes the length of the diameter of a circle, s the length of a chord and a the height of the arc corresponding to this chord then

$$s = [d^2 - (d - 2a)^2]^{1/2}.$$

The various operations in the solution of the problem seem definitely to prove that the equivalent of this relation was familiar to the Babylonians of 2000 B. C. The text is as follows:

1 [= 60] the circumference, 2 the perpendicular, to find the chord. Do as follows, square 2, thou seest it is 4. Subtract 4 from the diameter 20 thou seest it is 16. Square the diameter 20 thou seest it is 6.40 [= 400]. Square 16 thou seest it is 4.16 [= 256]. Subtract 4.16 from 6.40 giving 2.24 [= 144] of which calculate the square root. The square root is 12. Such is the procedure.

This solution brings out, what may be checked in other parts of *CT*.IX, that 3 was the value of π used by the Babylonians. It will be recalled that this was the value we find in the Bible, for example, in I Kings 7: 23, which was written about 560 B. C. and may have been taken from temple records dating back to 900 B. C. This verse is as follows: "And he made a molten sea, 10 cubits from one brim to the other: it was round all about, and his height was 5 cubits and a line of 30 cubits did compass it round about." We note also that the proposition of Thales of Miletus that the angle in a semi-circle is a right angle was visualized by the Babylonians 1,400 years earlier, and that a study was made of chords of a circle long before the days of Hipparchus.

The second problem in *CT*.IX to which we have referred is to find a given $d = 20$ and $s = 12$; each step is equivalent to substitution in the formula

$$a = 1/2[d - (d^2 - s^2)^{1/2}].$$

Other results in *CT*.IX are: (*a*) The area of a circle is one twelfth the square of the length of its circumference; (*b*) the volume of the frustum of a cone is one half the sum of the areas of the circular bases times the distance between them.

Another series of problems of great mathematical interest is found on tablets of about 2000 B.C. in the library of the University of Strasbourg. These were published with a translation in 1928 by Carl Frank[52] and their meaning was ingeniously elaborated this year by Neugebauer.[53] The problems treat of various

[49] E. F. Weidner, "Die Berechnung rechtwinkliger Dreiecke bei den Akkadern um 2000 v. Chr.," *Orientalestische Literaturzeitung*, v. 19, 1916, cols. 257–263; see also commentary by A. Ungnad, cols. 363–368, and by H. Zimmern, cols. 321–325. A reference may be given also to O. Neugebauer, "Zur Geschichte des Pythagoräischen Lehrsatzes," Gesellschaft der Wiss. zu Göttingen, *Math.-phys. Kl., Nachrichten*, 1928, p. 45–48.

[50] H. V. Hilprecht, "Mathematical, Metrological and Chronological Tablets from the Temple Library of Nippur," Philadelphia, 1906, p. 24.

[51] O. Neugebauer and W. Struve, "Über die Geometrie des Kreises in Babylonien," *Quellen und Studien zur Geschichte der Mathematik, Abteilung B: Studien*, Berlin, 1929, p. 89–92.

[52] C. Frank, "Strassburger Keilschrift Texte in sumerischer und babylonischer Sprache," Strassburger Wissenschaftlichen Gesellschaft in Heidelberg, *Schriften*, n.s., part 9, Berlin and Leipzig, 1928.

[53] O. Neugebauer, "Zur Geschichte der babylonischen Mathematik," *Quellen und Studien zur Geschichte der Mathematik, Abt. B, Studien*, v. 1, 1929, p. 67–80.

sections of a right triangle by lines drawn parallel to the base, which is regarded as horizontal, the vertex being below the base. In problem 10, two lines are drawn parallel to the base and the figure consisting of the two adjacent trapezia is considered. The area of the upper trapezium is given as 783, of the lower as 1,377. The difference of the base (b) and the lower dividing line (d_2) is given as 36. It is also given that the difference between the base and the upper dividing line (d_1) is one third of the difference between the upper and lower dividing line. It is required to find five unknown quantities: the lengths of the base and of the two dividing lines, and the altitudes of the trapezia (h_1 and h_2). The various statements above lead us to the following relations: $(1/2)h_1(d_1+b)=783$; $(1/2)h_2(d_2+d_1)=1377$, $b-d_2=36$, $b-d_1=(1/3)(d_1+d_2)$. It follows from this last equation and from similar triangles that $h_2=3h_1$, and from these five relations between five unknown quantities it is found that $b=48$, $d_1=39$, $d_2=12$, $h_1=18$, $h_2=54$. The mere formulation of such a problem gives a striking impression of the mathematical capabilities of the Babylonians. Neugebauer seems to have thought that as a result of this problem we might say that they knew how to solve five equations in five unknown quantities. To me such a suggestion is highly misleading; the much more natural deduction is that the Babylonians had developed considerable insight into geometrical relations (further examples of this might be shown[54] if time permitted), and solved the problem entirely from geometrical considerations. This would imply, in particular, that they were familiar with the result that similar right triangles have the sides about the right angles proportional, a theorem which our mathematical histories connect with Thales.

In another problem a right triangle is divided into five parts by four lines drawn parallel to the base, and from certain data other parts are to be found. In yet another, a triangle is divided into two parts (a trapezium and a triangle) by a single dividing line (of length d) parallel to the base, which is given as 30 units in length. The altitude of the triangle is given as 10 units greater than h_1, the altitude of the trapezium, and the area of the triangle is given as 270. Whence $270=(1/2)d(h+10)$; making use of the result regarding similar right triangles referred to above, we would have also $d:(h+10)=30:(2h+10)$ from which, according to methods of to-day, we would be naturally led to a quadratic equation for determining h. Neugebauer notes two other similar problems the discussion of which leads to quadratic equations whose solution is called for by the problem. It is exactly in connection with these questions, however, that details as to the solutions of the questions are lacking. Were it not for a note at the end of the article we might incline to regard the introduction of quadratic equations as out of keeping with the mathematics discussed. In this note, however, Neugebauer states that in another problem of *CT.*IX the discussion leads to the quadratic equation

$$x^2-\frac{2F}{d}x+\frac{2Fh}{d}=0$$

and that the solution follows step for step by substitution in the formula:

$$x=\frac{F}{d}-\left[\left(\frac{F}{d}\right)-\frac{2Fh}{d}\right]^{1/2}.$$

In an article published last August Wieleitner reported[55] that he had inspected an unpublished manuscript of Neugebauer and was thoroughly convinced by the evidence adduced that the Sumerians of 2000 B. C. understood how to solve problems which led to a general quadratic equation—a new fact of very extraordinary interest. It was previously supposed that Heron of Alexandria who flourished about 250 A. D. was the first to use our modern method of solving a quadratic equation.[56]

Although more a matter connected with astronomy, we may possibly under the head of geometry consider the Babylonian divisions of a circle. Bosanquet and Sayce stated[57] with great definiteness that the divisions which are found are those into 8, 12, 120, 240 and 480 parts; that we do *not* find the division into 360 parts as commonly supposed; and that while the division of the circle as practiced by Ptolemy and in modern times is an outgrowth of the sexagesimal method of the inscriptions, the latter does not contain the former. In support of his argument the authors quote an Akkadian tablet[58] in the British

[54] For example, see C. J. Gadd, "Forms and Colours," *Revue d'Assyriologie et d'Archéologie Orientale*, 19: 149–158, 1922. The article is mainly descriptive of a British Museum tablet of about 2000 B. C. on which are drawn about a dozen figures involving squares and arcs of circles. At least two of the figures suggest either the study of various geometrical forms for their own sake or the application of such designs in artistic ornamentation.

[55] *Archiv für Geschichte der Mathematik, der Naturwissenschaften, und der Technik*, 12: 107.

[56] T. L. Heath, "History of Greek Mathematics," Oxford, 1921, vol. 2, p. 306, 344.

[57] R. H. M. Bosanquet and A. H. Sayce, "The Babylonian Astronomy," Royal Astronomical Society, *Monthly Notices*, 40: 108–109, 1880.

[58] First published, in part, by E. Hincks, in *Literary Gazette*, 38: 707, 1854, who surmised that the numbers referred to the portions of the moon visible on each of the first fifteen days of the month. This view was repeated by Hincks in Royal Irish Academy, *Polite Literature, Transactions*, 22: 407, 1855, and repeated by Cantor, Tropfke and Karpinski (see my Bibliography under Hincks, 1854 suppl.). They seem to have overlooked the correct interpretation.

Museum containing a record of the moon's longitude during thirty days; these numbers during the first fifteen days of its advance are: 5, 10, 20, 40, 80, 96, 112, 128, 144, 160, 176, 192, 208, 224, 240; then follow retrograde numbers 224, 208, 192, etc., the moon's daily motion being, for the most part, 16 out of 480 divisions of a circle, as it should be roughly. In a tablet from Sennacherib's palace (about 700 B. C.), now in the British Museum, a circle is divided into 480 equal parts.[59]

On the other hand, in discussing geometry of the Babylonians, Cantor states:[60] "for a certainty we have the division of a circle into 6 parts, then into 360 degrees." Heath's discussion of the question[61] involves no such positive statement, but he does note that it was Hipparchus, about 50 B. C., who first divided the circle in general into 360 parts or degrees, and that the introduction of this division coincides with his invention of trigonometry. In an article published by Thureau-Dangin last year[62] it was argued that the division of the circle into 360 parts by the Babylonians was "natural," but that further sexagesimal division was unnatural; also that the Babylonians made use of the division of the circle as learned from the Sumerians. It has appeared to me that the evidence favors the view of Bosanquet and Sayce that the division of the circle into 360 parts did *not* originate with the Babylonians.[63]

And finally, in connection with Babylonian geometry, there does not seem to be any problem where an expression for volume is clearly stated. It is true that Hilprecht discussed such an example but he was in doubt as to whether the object was a rectangular parallelopiped or not.

EGYPTIAN GEOMETRY

Let us first consider the problems of a geometrical nature, found chiefly in the Rhind and Golenishchev papyri. In the Rhind papyrus there are nineteen problems of this kind, namely: nos. 41–46, 48–60. The first six problems deal with volumes and the next eight with areas. In the first three are found volumes of circular cylindrical granaries of different diameters and heights. In each the process consists in multiplying the height by the area of the base which is found by the uniform rule of squaring eight ninths of the diameter of the base. This leads us to the value $256/81 = 3.1605\ldots$ for π, a very remarkable approximation, used also in the Golenishchev papyrus and therefore practically contemporary with the Babylonian use of $\pi = 3$, about 2000 B. C. This same method of discussing the area of a circle is found in problem no. 48, where the areas of a circle and its circumscribed square are compared, and in no. 50, where the area of a round field of given diameter is asked for.

Among various writers who have conjectured how the Egyptian arrived at such a rule for the area of a circle are Demme, Simon and Vacca. In essence Simon's conjecture, which seems the most plausible, amounts to the following:[64] Suppose that two vessels of the same height, one with a circular base and the other with a square base equal to the circumscribed square of the circle, are filled with water. Then by weighing the water in each container it would be found that the quantities are as 64 to 81. Hence the result of problem no. 48 with reference to the relative areas of a circle and its circumscribed square would be found, and the rule for finding the area of a circle derived.

In problems 44 to 46 are discussed volumes and dimensions of parallelopipedal granaries. In other problems the area of a rectangular field of given dimensions is found, sections of a triangle similar to those considered by the Babylonians are discussed and two problems of the following type are solved: What equal areas should be taken from 10 fields if the sum of these areas is to be 7 setat?

Problem 51 is to find the area of a triangle given its base and altitude and 52 to find the area of a trapezium with apparently equal slanting sides, the lengths of the parallel sides and the distance between them being given numbers. These two problems have been the topic of many pages of discussion during the past fifty-three years. Some of the questions involved may be briefly set forth. In no. 51 the figure is a fairly good approximation to an isosceles triangle; beside the base and one of the sides are written certain numbers, half the product of which is given as the area of a triangle. Did the author of the papyrus think that the area of an isosceles triangle was one half the length of the base times the length of a side? Or was this triangle intended to be regarded as right angled and not isosceles? And, similarly in problem 52, did the author think that the area of the trapezium is one half the sum of the lengths of the parallel sides times the length of a

[59] D. E. Smith, "History of Mathematics," vol. 2, Boston, 1925, p. 230.

[60] M. Cantor, "Vorlesungen über Geschichte der Mathematik" vol. 1, 3rd ed., Leipzig, 1907, p. 50.

[61] T. L. Heath, "History of Greek Mathematics," vol. 2, 1921, p. 214–216.

[62] *Revue d'Assyriologie et d'Archéologie Orientale*, 25: 187–88, 1928.

[63] The weighty authority of B. Meissner ("Babylonien und Assyrien," vol. 2, Heidelberg, 1925, p. 385) favors the 360 division of the circle by the Babylonians; but the statement is made in such a way as to suggest that Meissner did not consider the question as carefully as he might have done.

[64] M. Simon, *Archiv d. Mathematik und Physik*, s.3, 9: 102, 1905.

slant height? Or was one side of the trapezium intended to be perpendicular to the parallel sides as in the case of those studied by the Babylonians?

In the great dedicatory inscription, of about 100 B. C., in the Temple at Edfu, as described by Lepsius, there are references to a large number of four-sided fields. For each of these the lengths of the sides (which we may call, in order as we go around, a, b, c, d) and their areas are given; these areas may be determined by the formula $(1/2)(a+c) \times (1/2)(b+d)$. If $a=c$, and b and d are parallel, we see that the Egyptians of 100 B. C. *did* use the formula that the area of a trapezium is equal to one half the sum of the parallel sides times the slant height, when these are equal. Moreover, if $a=c$, $d=0$, we get $\frac{1}{2}ab$ as the area of an isosceles triangle which is illustrated on the Edfu inscription by two examples $a=c=17$, $b=5$, area 85/8; $a=c=3$, $b=2$, area 3. These rules for calculating the areas of four-sided and three-sided fields are precisely those used by Egyptian natives to-day.[65]

It is, therefore, all the more interesting that in the period which we are considering the correct formulas were used for the areas of a triangle and a trapezium. The final proof of this, even when the figures are not isosceles, is given in papers published by Gunn and Peet in 1926 and last month.[66] The proof is based upon the analysis of the meaning of certain Egyptian words and of problem 4 of the Golenishchev, which is identical with no. 51 of the Rhind papyrus.

Five of the six remaining geometrical problems in the Rhind papyrus deal with the relation of the lengths of two sides of a right triangle which corresponds to the cotangent of the angle which a face of a regular pyramid makes with its base. This is called the *seked* of the pyramid. The seked 18/25 in problem 56 has been associated with the slope of the lower half of the southern stone pyramid of Dahshur, and the seked 3/4 in problems 57–59 with the slope of the second pyramid of Gizeh. The absurdities of such associations, even as made by Heath, I have recently shown elsewhere.[67]

Of six geometrical problems in the Golenishchev papyrus we have already noted the identity of no. 4 with a problem of the Rhind papyrus. In no. 6 we are given a rectangular enclosure of 12 units area and the ratio of the sides as 1:3/4 [1/2 1/4]; the lengths of the sides are found. The problem seems to be practically identical with one in the contemporary Kahun papyri in London. The solution of this problem may be regarded as equivalent to solving the simultaneous equation $xy=12$, $x:y=3/4$ [$-1/2$ 1/4]. For the steps of the solutions in both papyri are as follows:

$$1:3/4=1\ 1/3;\ 1\ 1/3 \cdot 12=16;$$
$$(16)^{\frac{1}{2}}=4\ [=x];\ 4 \cdot 3/4=3\ [=y].$$

Two other geometrical problems in Berlin papyri fragments of about 1850 B. C. may be said to lead to simultaneous quadratic equations which are solved by the method of false position. The first of these is as follows:

Distribute 100 square ells between two squares whose sides are in the ratio 1 to 3/4; the corresponding equations[68] are $x^2+y^2=100$, $x:y=1:3/4$. The solution is as follows: Try $x=1$, $y=3/4$, then $x^2+y^2=25/16$ [$=1\ 1/2\ 1/16$]. But $(25/16)^{\frac{1}{2}}=5/4$ [$=1\ 1/4$] and $(100)^{\frac{1}{2}}=10$. $10:5/4=8$, whence[69] $x=1 \cdot 8=8$, $y=6$.

But while there is equivalence between the solutions of these ancient Egyptian problems and the solution of our algebraic simultaneous equations, so far as we know the Egyptian had none of our modern algebraic conceptions in this connection; he used methods which are wholly arithmetic, the idea of ratio and proportion being an important element. Cantor[70] and Tropfke[71] seem to be somewhat misleading in this regard.

The correct interpretation for no. 7 of the Golenishchev papyrus was given only last month by Gunn and Peet. It is: "A triangle of given area is such that its altitude is $2\frac{1}{2}$ times its base; find both." The authors make clear that no. 17 is a similar problem for a scalene triangle.

But problems 14 and 10 of the Golenishchev papyrus contain the most extraordinary results in ancient geometry. In the first of these the conclusion is unavoidable that the Egyptian of about 1850 B. C. was

[65] B. Gunn, *Journal of Egyptian Archaeology*, 12: 133, 1926.

[66] B. Gunn, *Journal of Egyptian Archaeology*, 12: 132–133, April, 1926. B. Gunn and T. E. Peet, *Journal of Egyptian Archaeology*, 15: 173–176, November, 1929.

[67] In my Bibliography.

[68] For the second problem, the equations are: $x^2+y^2=400$ and $x:y=2:1\frac{1}{2}$.

[69] We may note the relation in this problem of $1^2+(3/4)^2=(5/4)^2$, which has $3^2+4^2=5^2$ as a basis. Contrary to what is popularly believed, there is nothing to prove that the Egyptian knew the theorem regarding the squares on the sides of right triangles even in special cases.

[70] M. Cantor, "Vorlesungen über Geschichte der Mathematik," vol. 1, third ed., 1907, p. 95–96. It is true that Cantor treats these problems under the head of geometry and after his discussion states (p. 96): "Wir möchten bitten diese ganze Untersuchung, welche ihrem algebraischen Inhalte nach schon in das vorige Kapitel [arithmetic and algebra] gohören könnte, nicht als hier an unrichtiger Platze stehend bemängeln zu wollen. Sind doch die behandelten quadratischen Gleichungen aus geometrischen Aufgaben entsprungen."

[71] Tropfke, "Geschichte der Elementar-Mathematik," second ed., vol. 3, 1922, p. 56–57; these pages are in Tropfke's history of equations of the second degree.

familiar with our formula for the volume of a frustum of a square pyramid $V=\frac{h}{3}(a_1^2+a_1a_2+a_2^2)$, where a_1 and a_2 are the sides of the square bases of the frustum, and h its height. Previous to 1917 it was not known that any particular case of the familiar general formula for the volume of the frustum of a pyramid given by Leonardo of Pisa in 1220 had been previously used. To learn then[72] that such a formula was known 3,000 years earlier was sufficient almost to revolutionize our ideas concerning the capability of the Egyptian as a geometer. Of course Heron of Alexandria, Brahmagupta and Mahāvīrācārya gave other forms for the volume of the frustum of a square pyramid. The exact text in this connection may be given:[73]

Example of calculating a truncated pyramid. If you are told: a truncated pyramid of 6 for the vertical height by 4 on the base by 2 on the top:

You are to square this 4; result 16. You are to double 4; result 8. You are to square this 2; result 4. You are to add the 16 and the 8 and the 4; result 28. You are to take 1/3 of 6; result 2. You are to take 28 twice; result 56. See, it is of 56.

You will find (it) right.

In a joint article, published last month by Gunn, Peet and Engelbach, detailed consideration was given to the question of how the Egyptian arrived at such a formula,[74] but to me their conclusions are not very convincing, even though we assume the great stage of their mathematical development which led them to the result of problem 10 which seems to be even more remarkable than the one just discussed.

In this problem taking the value of π used in the Rhind papyrus, the area of a hemisphere is found correctly, a result till recently supposed unknown before the time of Archimedes 1,600 years later. If d be the diameter of a hemisphere, each step of the work is equivalent to substitution in the formula:

$$S=[(2d-2d/9)-(1/9)\ (2d-2d/9)]\cdot d$$

which may be simplified to give $S=(1/2)(256/81)d^2$.

In concluding the survey of Egyptian geometry, reference may be made to a theory of F. G. Röber[75] who, from the study of ancient temple architecture and of the Temple of Edfu in particular, seemed to have divined that the layout was intimately connected with the construction of a regular heptagon. Over the ruler and compasses construction for this heptagon indicated by Egyptian architecture Sir William Rowan Hamilton grew highly enthusiastic; he showed[76] that the cosine of the angle subtended by a side of the heptagon thus constructed agreed to within two units in the seventh place of decimals with the value for the cosine of the seventh part of four right angles.

Concluding Comment

Time will not allow me further to elaborate my topic. We have obtained some glimpses of the extraordinary mathematical achievements of the Egyptians during the golden period of their activity between 1600 and 1900 B. C. So far as we know at present practically no advance was made by them at a later date. We have met with some results, and many others could be adduced, which seem conclusively to show that the Egyptian studied mathematics for its own sake, and not alone for its practical applications. Breasted was led to make a similar deduction in connection with medical science after studying the remarkable Edwin Smith medical papyrus, soon to be published, which is also a document of the golden period of mathematical activity. What does the future have in store for the extension of our knowledge of Egyptian mathematics? The Golenishchev papyrus is to be published completely in the near future, but there are no other known unpublished Egyptian mathematical documents of this ancient period.[77]

We have seen that even our present knowledge of Babylonian mathematics indicates notable achievements, and suggests that they too must have studied mathematics for its own sake. But since there is a great deal of important Babylonian mathematical material in London, Berlin and elsewhere, its published interpretations hold extraordinary promise for the future enrichment of our knowledge of mathematics in these early days.

Until recently we have connected the Babylonians more with astronomical than with mathematical achievement, for they were famed for their knowledge of the heavens, and the pseudoscience of astrology originated with them. They were acquainted with the

[72] B. A. Turaev, *Ancient Egypt*, 1917, p. 100–102.

[73] Gunn and Peet, *Journal of Egyptian Archaeology*, 15: p. 176.

[74] *Journal of Egyptian Archaeology*, 15: 179–184.

[75] F. Röber, "Beiträge zur Erforschung der geometrischen Grundformen in den alten Tempeln Aegyptens und deren Beziehung zur alten Naturerkenntniss," Dresden, 1854, p. 15–16.

F. Röber, "Elementar-Beiträge zur Bestimmung des Naturgesetzes der Gestaltung und des Widerstandes, und Anwendung dieser Beiträge auf Natur und alte Kunstgestaltung," Leipzig, 1861, p. 20–22.

[76] *Philosophical Magazine*, s. 4, 27: 124–132, 1864; R. P. Graves, "Life of Sir William Rowan Hamilton," vol. 3, Dublin, 1889, p. 141–148, 581–587. For other details in this connection see my Bibliography under 1854, and my notes in *American Mathematical Monthly*, 28: 477–479, 1921.

[77] I have referred in my Bibliography to a large unpublished geometrical Greek papyrus in Vienna found in the Fayûm and dating from about 350 B. C.

five planets Mercury, Venus, Mars, Jupiter and Saturn, distinguished the signs of the zodiac and made long lists of the fixed stars. The chief duty of the astronomer was to observe the moon for the purpose of keeping the calendar.[78] Their predictions of eclipses were made by a rule based upon the empirical discovery that there was a period of a little over eighteen years within which eclipses repeat themselves.[79]

That Greek astronomy was based on the astronomy of the Babylonians is well known. We have noted that certain mathematical results regarded as original with the Greeks must, from now on, be attributed to the Babylonians and to the Egyptians. But whatever new facts are found concerning mathematics before the Greeks, the glory of their achievements in creating a vast body of deductive geometrical reasoning is not likely ever to be dimmed.

OBITUARY

EDWARD DRAKE ROE, JR.

DR. EDWARD DRAKE ROE, JR., for twenty-nine years professor of mathematics at Syracuse University, died suddenly at his home in Syracuse on Wednesday, December 11.

Dr. Roe had a long and distinguished career as student, educator, mathematician and astronomer. He received his bachelor's degree from Syracuse University in 1880. He then went to Harvard University where he first studied medicine and then returned to his studies in mathematics. He received a bachelor's degree from Harvard in 1885 and a master's degree in 1886. After teaching a few years, he went to the University of Erlangen, Bavaria, where he won his doctorate in 1898. He returned to America and was made associate professor of mathematics at Syracuse University.

In 1901 he was awarded the John Raymond French chair of mathematics and some years later was appointed director of the Holden Observatory of Syracuse University.

Dr. Roe built his own private observatory in connection with his own house. It was equipped with an Alvan Clark equatorial telescope and is considered one of the best-equipped private observatories in the country.

He was the author of nearly seventy scientific articles on mathematics, astronomy and philosophy. He was the author of a text-book in trigonometry and one in algebra.

He was the founder and director general of the honorary mathematical fraternity, Pi Mu Epsilon, and was a member of the Phi Beta Kappa, Sigma Xi, Pi Kappa Phi and Delta Kappa Epsilon. He was a fellow of the American Association for the Advancement of Science, a member of the American Mathematical Society, the founder and president of the Syracuse Astronomical Society, a member of the Deutsche Mathematiker Vereinigung, Circolo Matematico di Palermo and Société Astronomique de France.

Dr. Roe stood for high scholarship, thorough scientific study and research. He impressed all who knew him as a scholar with a deep thirst for knowledge. He worked with untiring patience in mathematics and its allied science astronomy in the university and in the community.

Throughout his years of service as a teacher Dr. Roe always stood for the highest ideals of intellectual honesty and scientific achievement. He was a devoted teacher, a deep thinker, a philosopher and an earnest Christian. In his death Syracuse University has suffered a distinct loss.

ALAN D. CAMPBELL

MEMORIALS

THE American Electrochemical Society has announced its intention of establishing the Joseph W. Richards Memorial Fund, the interest of which is to be used as an honorarium to foreign electro- and physical chemists who are to be invited by the society from time to time. The guests will present lectures at annual spring conventions of the American Electrochemical Society, and possibly at universities and other institutes of learning. Professor Richards was secretary of the American Electrochemical Society for almost twenty years and was very largely responsible for the founding of the society. He was ever a very strong advocate in fostering better relations between our own scientists and scientists abroad, inviting and entertaining many notables at his own expense. The many friends of Professor Richards, therefore, feel that this memorial to him is a most fitting one. All those interested are invited to send their contributions to the secretary of the American Electrochemical Society, Columbia University, New York City, making all checks payable to the Joseph W. Richards Memorial Fund. It is the desire of the Board of Directors of the society that the list of contributors include as many as possible of Professor Richards'

[78] British Museum, "Guide to the Babylonian and Assyrian Antiquities," London, 1922, p. 25.

[79] For a summary of Egyptian astronomy see T. E. Peet, "The Sciences" in "The Cambridge Ancient History," Cambridge, vol. 2, 1924, pp. 218, 656.

friends and acquaintances, and subscriptions in any amount are invited.

Industrial and Engineering Chemistry reports that the debt of modern science and industry to Karl Wilhelm Scheele, distinguished Swedish chemist and discoverer of glycerol, was recognized at the annual meeting in Chicago on December 11 of the Association of American Soap and Glycerine Producers, representing the leading soap manufacturers of the country. The association sent to Crown Prince Gustaf Adolf, honorary member of the Royal Academy of Sciences of Sweden, a message felicitating him on the part played by his country in the development of glycerol products. December 19 marked the one hundred and eighty-seventh anniversary of Scheele's birth, and 1930 marks the sesquicentennial of his discovery.

THE London correspondent of the *Journal* of the American Medical Association writes: "Sir Patrick Manson, who died in 1922, established the principle of the insect transmission of disease, and at the international medical congress held in London in 1913 he was acclaimed the father of tropical medicine. In 1907, with the help of Cantlie and others, he founded the Society of Tropical Medicine and Hygiene, of which he was the first president. Among its fellows, now numbering 1,500 of many nationalities, are those most distinguished in tropical medicine. Its work is hindered by lack of suitable premises. The society has decided to found a home and name it after Manson, to whom at present there is no memorial. The fellows and some friends have subscribed $30,000 toward the purpose and are appealing for $100,000 to which they believe that many outside the small professional circle of tropical medicine who know of Manson's labors as a leader of medicine and one of the world's benefactors will desire to subscribe. His great work began in Amoy in 1877 with his demonstration that the filaria of elephantiasis is transmitted by certain mosquitoes. This was no chance discovery but the result of labor done in isolation. So his conviction that malaria was transmitted by mosquitoes was no inspired guess but was founded on his long critical watching of the malarial parasite in human blood and led Ross to the final victory. Donations will be gratefully received by the Royal Society of Tropical Medicine, 11 Chandos Street, Cavendish Square, London, W 1."

RECENT DEATHS

DR. FLETCHER BASCOM DRESSLAR, professor of school hygiene in the Peabody College for Teachers, died on January 19, at the age of seventy-one years. Dr. Dresslar had been president of the Tennessee Academy of Sciences.

PHILIP NORTH MOORE, consulting geologist and mining engineer, president of the American Institute of Mining Engineers in 1917, died on January 20 at the age of eighty years.

STEPHEN TYNG MATHER, who was director of national parks in the Department of the Interior, died on January 22 at the age of sixty-two years.

DR. CAROLINE A. BLACK, who had been twelve years on the faculty of Connecticut College, latterly as associate professor of botany and chairman of that department, died on January 19 at Cincinnati, Ohio, of spinal meningitis. She was taken ill when returning from the American Association for the Advancement of Science meeting at Des Moines.

HUGH LONGBOURNE CALLENDAR, professor of physics at the Imperial College of Science, London, died on January 23, at the age of sixty-six years. He was distinguished for his work in connection with the measurement of the heat radiation of steam at high pressure. Dr. Callendar was professor of physics at McGill University from 1893 to 1898.

MAJOR PERCY ALEXANDER MACMAHON, F.R.S., the distinguished English mathematician, died on Christmas Day at his residence at Bognor, at the age of seventy-five years.

DR. DE FERRANTI, electrical engineer, inventor and manufacturer, died on January 14 at the age of sixty-five years. Dr. Ferranti was a past president of the British Society of Electrical Engineers. He was awarded the Faraday Medal of the Institution of Electrical Engineers in 1924, and was elected a fellow of the Royal Society in 1927. The University of Manchester gave him the honorary degree of D.Sc. in 1911.

SCIENTIFIC EVENTS

COMMISSIONS OF THE INTERNATIONAL GEOLOGICAL CONGRESS

IN its report of the congress *Nature* states that during the session a series of meetings was held in connection with the various international commissions, the work of which is an important feature in the life of the congress. In the end, several commissions had to be reconstituted, one new commission and one subcommission were established, while of the previous bodies, one (iron ores) was dissolved, so that the Congress now has the following commissions: Prix Spendiaroff (awarded to Dr. L. T. Nel, geologist on the Geological Survey of the Union of South Africa), Palæontologia Universalis, Lexicon de Stratigraphie, Glaciers, L'Homme Fossile, Croûte Terrestre, Géophysique et Géothermique, Carte de l'Europe, Carte

de la Terre, Distribution of the Karroo (Gondwana) System; to these was added the subcommission of African Surveys.

It is said that since the last meeting of the congress, in Spain during 1926, much useful work has been accomplished by the two map commissions, under the chairmanship of Dr. P. Krusch, president of the Geological Survey of Prussia. The one for the map of Europe on the scale of 1:1,500,000 was founded at Bologna in 1881, and shortly after the Toronto congress in 1913 completed its task by publishing the last sheet, and the preparation of a new edition was afterwards decided upon. The indispensable preliminary work of agreeing upon the best color scheme was completed at a meeting of the commission held in Berlin last February, and during the South African meeting Dr. W. Schriel (general secretary of the commission) exhibited two advance sheets of the new edition, in their original form; the great beauty of the color scheme and the excellence of the draftsmanship were much admired by many members. One section of the new edition is ready for the press and further sections are expected to appear at the rate of two in each year.

The publication of the International Map of the World on the scale of 1:5,000,000 was decided upon at the Stockholm congress in 1910, and the color scheme drafted at the Berlin meeting referred to, two sections embracing the Union of South Africa being afterwards prepared; they were presented at the Pretoria meeting. For the next congress it was agreed to prepare a few North American sections.

The final editing is to be done at Berlin (as was formerly the case) in order to secure uniformity of issue, for which purpose a special bureau has been established at Berlin. Dr. P. Krusch (chairman of both map commissions) was able to announce the fortunate circumstance that the means for the printing of both maps have been made available by Prussia, so that in due course the sheets will be obtainable through the Geological Survey of that country.

THE GREAT SMOKY MOUNTAIN NATIONAL PARK

THE states of North Carolina and Tennessee have notified the secretary of the interior that they have acquired and are ready to turn over to him a minimum of 150,000 acres of land in what is ultimately to constitute the Great Smoky Mountain National Park on their border line. Representatives of these two states, including their governors and attorneys general, and members of their park commissions, will go to Washington on February 6 and formally tender to Secretary Wilbur the title to this initial area, duly passed and warranted by the states.

This action on the part of these two states will mark the first delivery of Great Smoky Mountain park land to the government and the first concrete step toward the actual consummation of the project. It will constitute the first physical transfer of land to the government and mark the passing of the Great Smoky Mountain project from a theoretical conception to an actual accomplishment. It means that the government actually will have received a tract of land more than twice as big as the District of Columbia as a nucleus around which to develop a model wilderness area into a national park of the east.

The law which provided for the creation of the Great Smoky Mountain National Park and the Shenandoah National Park made their acceptance by the government conditional upon the presentation of complete title to the land. The states must acquire the land and deliver it to the federal government. It would then be placed under the National Park Service for administration and development.

Investigations had shown there were practically 704,000 acres of land in the Great Smoky Mountain district, an area as big as Rhode Island, that was suitable for park purposes. The law provided that when a minimum of 150,000 acres of this land was presented to the government, it should be accepted and that the government should thereafter administer and protect it. This, however, was to be but a nucleus of the contemplated park.

The law further provided that the states must acquire and present to the federal government, in addition to this 150,000 acres, the majority of the remaining available park land in this section. That available remaining land amounts to 554,000 acres. Half of it would be 277,000 acres which must yet be acquired by the states and presented to the federal government before it will consider the park area adequate and proceed with its actual development. It will accept the lesser area for administration and protection, but not for development. When it has received a minimum of 427,000 acres from the states of North Carolina and Tennessee, an area as big as seven Districts of Columbia, the National Park Service will proceed to develop it on a basis comparable to that used at Yellowstone, Yosemite and other of the great national parks in the west.

The acquisition of the minimum acreage required before development work may begin seems assured. The states of North Carolina and Tennessee between them have raised, in round numbers, nearly $5,000,000 to be used in the purchase of this land. The Laura Spelman Rockefeller Memorial has contributed an additional amount, but not exceeding $5,000,000, which is also available for the purchase of land. These

amounts are considered adequate for the acquisition of the minimum area required by the law. That acquisition but awaits the details of purchase, the local examination of titles and, in some cases, condemnation procedure where it is necessary. It would appear, therefore, that the establishment of a Great Smoky Mountain National Park, with the delivery of land titles on February 6, will pass into the final stages of actual accomplishment.

INTERNATIONAL EXPEDITION TO THE BAHAMAS UNDER THE AUSPICES OF PRINCETON UNIVERSITY

PLANS have been completed for an international expedition to the Bahamas under the auspices of Princeton University, from February 1 to April 15. The expedition is under the direction of Professor R. M. Field, of Princeton University, and is being supported by Mr. Hugh Matheson, of Miami, who is lending his yacht the *Marmion*, and with the cooperation of the following institutions:

The Percy Sladen Trust of London
The Rouse Ball Fund of Trinity College, Cambridge
Die Notgemeinschaft der Deutschen Wissenschaft
The U. S. Coast and Geodetic Survey
The American Museum of Natural History
The Buffalo Society of Natural Sciences
State of New Jersey Agricultural Experiment Station
The International Summer School of Geology and Natural Resources

The subjects of research and the personnel are as follows:

1. *Navigation:* Mr. Hugh Matheson, Miami.
2. *Gravity Determinations:* Under the direction of Dr. William Bowie, of the U. S. Coast and Geodetic Survey. Ensign Joseph P. Lushene in charge of field work.
3. *Marine Biology:* Professor Ulric Dahlgren, department of biology, Princeton University. Dr. Roy W. Miner, curator of invertebrate zoology, American Museum of Natural History.
4. *Bacteriology:* Dr. S. A. Waksman, State of New Jersey Agricultural Experiment Station, Rutgers University. Dr. Werner Bavendamm, Technische Hochschule, Dresden.
5. *Geology: Percy Sladen Trust Expedition to Andros Island.* Mr. Maurice Black, fellow of Trinity College, Cambridge, and Commonwealth Fund fellow, department of geology, Princeton University.
6. *Marine Sedimentation:* Professor R. M. Field, department of geology, Princeton University, and research associate, Buffalo Society of Natural Sciences. Dr. Ernest Dixon, British Geological Survey.
7. *Oceanography:* Dr. Charles Fish, Buffalo Society of Natural Sciences.

The purpose of the expedition is to continue the study of the physical, chemical and biological conditions governing the character of the sediments in the region, as well as the effect which these sediments have upon the life and habits of the marine organisms.

The expedition is expected to yield new and interesting data concerning oceanographic and biologic problems, and it is hoped that the results obtained will supply information which will be of aid in interpreting certain geological problems, such as the origin of limestones and dolomites and the habitats of marine organisms in the ancient tropical seas. One of the fundamental geological problems in this region is the question of the origin of the islands, as well as the relation of their stability to the character of the sediments which mantle their surfaces.

BRITISH HONORS

Nature reports that the New Year Honors list of Great Britain contains the names of the following men of science and others associated with scientific work: *Baronets:* Sir Gregory Foster, who has retired from the post of provost of University College, London, and was recently vice-chancellor of the university; Sir Eustace Tennyson-D'Eyncourt, at one time director of naval construction, admiralty. *K.C.M.G.:* Lieutenant-Colonel Andrew Balfour, member of the Colonial Advisory Medical and Sanitary Committee and director of the London School of Hygiene and Tropical Medicine. *Knights:* Professor T. P. Nunn, principal of the London Day Training College and professor of education in the University of London; Mr. Archibald Page, chief engineer and manager of the Central Electricity Board and a past president of the Institute of Electrical Engineers; Mr. Alexander Rodger, inspector-general of forests, Government of India; Professor T. Zammit, curator of the museum, Malta. *C.I.E.:* Mr. B. C. Burt, Imperial Council of Agricultural Research, India; Mr. H. L. Newman, chief conservator of forests, Bombay; Mr. S. Walker, chief engineer and secretary for irrigation, North-West Frontier Province, India. *C.B.E.:* Professor J. S. S. Brame, professor of chemistry and metallurgy, Royal Naval College, Greenwich; Mr. G. E. S. Cubitt, lately conservator of forests, Straits Settlements and Federated Malay States; Captain A. T. A. Dobson, assistant secretary, Ministry of Agriculture and Fisheries. *O.B.E.:* Mr. Joseph Jones, formerly curator of the Botanic Gardens, Dominica; Mr. W. A. S. Lamborn, medical entomologist, Nyasaland Protectorate; Captain R. N. Liptrot, principal technical officer, Air Ministry; Mr. W. R. Mustoe, superintendent of horticultural operations; Delhi; Dr. E. S. Russell, director of

fishery investigations, Ministry of Agriculture and Fisheries. *M.B.E.:* Mr. John Aikman, assistant, Royal Botanic Gardens, Kew; Mr. E. A. Bearder, technical adviser, Dyestuffs Advisory Licensing Committee; Mr. A. A. Gomme, librarian, Patent Office, Board of Trade.

SCIENTIFIC NOTES AND NEWS

PROFESSOR GILBERT N. LEWIS, dean of the college of chemistry in the University of California, has been elected an honorary member of the Swedish Academy of Sciences.

DR. J. S. PLASKETT, director of the Dominion Astrophysical Observatory at Victoria, B. C., has been awarded the gold medal of the Royal Astronomical Society, London, "for his valuable observations of stellar radial velocities, and the important conclusions derived from them."

PROFESSOR WILLIAM H. BRAGG, Fullerian professor of chemistry at the Royal Institution, London, and Dr. Godfrey Harold Hardy, professor of geometry at the University of Oxford, have been elected members of the Prussian Academy of Sciences.

THE council of the British Institution of Electrical Engineers has made the ninth award of the Faraday Medal to Sir Ernest Rutherford, Cavendish professor of experimental physics and director of the Cavendish Laboratory at the University of Cambridge. The medal is awarded for notable scientific or industrial achievement in electrical engineering or for conspicuous service rendered to the advancement of electrical science, irrespective of the recipient's nationality.

M. CHARLES NICOLLE, head of the Pasteur Institute at Tunis, has been elected a member of the French Academy of Sciences. Dr. Nicolle was awarded a Nobel Prize in 1928. He discovered the bacillus of typhus and that of the "Mediterranean fever."

THE University of Edinburgh has conferred the doctorate of science on Professor R. S. Adamson for his studies in plant ecology and plant anatomy.

DR. WALTER B. CANNON, George Higginson professor of physiology at the Harvard Medical School, who is Harvard exchange professor at the Sorbonne, Paris, has been appointed Linacre lecturer for 1930 at the University of Cambridge.

PROFESSOR OTIS EVERETT RANDALL, professor of applied mathematics at Brown University, where he has taught since 1885, will retire in June, having reached the age limit of seventy years.

THE staff and students, including many former students, of the Osborn Zoological Laboratory at Yale University, on January 13 celebrated the sixtieth birthday of Dr. Ross G. Harrison, Sterling professor of biology and director of the laboratory. During the afternoon a reception for Dr. Harrison was held in the building, at which a handsome watch, appropriately inscribed, was presented to him on behalf of the staff and students by Professor W. R. Coe, senior member of the departmental faculty. Dr. S. R. Detwiler, professor of anatomy at Columbia University, one of Professor Harrison's early students, presented to him the current volume of the *Journal of Experimental Zoology,* entirely composed of contributions by Dr. Harrison's students and prefaced by his portrait. Later an informal dinner was held at the Faculty Club. In addition to congratulatory telegrams and letters from many individual biologists at home and abroad, Dr. Harrison received felicitations from the Statione Zoologica at Naples, the Kaiser-Wilhelm Institut für Biologie at Berlin and the Medical Faculty of the University of Bonn where he received the degree of M.D. thirty years ago. The University of Freiburg conferred upon him the honorary doctorate of philosophy.

THE Swedish Geographical Society has presented its medal to General Umberto Nobile, Italian commander of the *Italia* Polar Expedition of two years ago. General Nobile lectured before the society on the expedition and paid a tribute to Finn Malmgren, who lost his life on the ice north of Spitzbergen.

THE Geological Society of London has this year made the following awards of medals and funds: The Wollaston Medal to Professor A. C. Seward, master of Downing College, and professor of botany in the University of Cambridge, for his researches in stratigraphy and palaeobotany; the Murchison Medal to Mr. A. L. Hall, of the Geological Survey of South Africa, for his researches on the stratigraphy and economic geology of South Africa; a Lyell Medal to Mr. F. Chapman, paleontologist to the federal government of Australia, for his work in paleontology (especially on the Foraminifera), and for his researches on the Tertiary rocks of Australia; a second Lyell Medal to Mr. H. B. Maufe, director of the Geological Survey of Southern Rhodesia, for his work on the geology and mineral resources of that colony; the Wollaston Donation Fund to Mr. E. G. Radley, of H. M. Geological Survey, for his work on the chemical analysis of rocks and minerals; the Murchison Geological Fund to Mr. John Smith, of Dalry, for his contributions to the geology and paleontology of Western Scotland; the Lyell Geological Fund to Miss

H. M. Muir-Wood, for her work on the paleontology of the Brachiopoda.

Dr. R. A. F. Penrose, Jr., of Philadelphia, formerly professor of geology in the University of Chicago, was elected president of the Geological Society of America at the recent annual meeting.

Dr. Alfred M. Tozzer, professor of anthropology and curator of Middle American archeology and ethnology at the Peabody Museum at Harvard University, has been elected president of the American Anthropological Association.

The Mineralogical Society of America held its tenth annual meeting at the Wardman Park Hotel, Washington, D. C., on December 26, 27 and 28, 1929, in conjunction with the Geological Society of America. The following officers were elected for 1930: *President,* Herbert E. Merwin, Geophysical Laboratory, Washington, D. C.; *vice-president,* John E. Wolf, Pasadena, California; *treasurer,* Albert B. Peck, University of Michigan; *secretary,* Frank R. Van Horn, Case School of Applied Science; *editor,* Walter F. Hunt, University of Michigan; *councilor,* 1930–33, Paul F. Kerr, Columbia University. Dr. Gregori Aminoff, director of the mineralogical department of the State Museum of Natural History, Stockholm, was elected a fellow.

Dr. Detlev W. Bronk has resigned his position as dean of men and professor of physiology and biophysics at Swarthmore College to become professor of biophysics and director of the Johnson Foundation for Medical Physics in the University of Pennsylvania.

Dr. Richard Bradfield, formerly associate professor of soils at the University of Missouri, has been appointed professor at the Ohio State University.

Professor J. H. Ashworth, of the department of zoology of the University of Edinburgh, known for his work on marine annelids, will have charge of the post-graduate seminar in zoology at the University of California from May 19 to June 28, 1930. He will arrive in New York early in April and before going to Berkeley will visit the large eastern universities and the government laboratories in Washington and during his stay will visit the principal biological laboratories in the United States.

The Mexican Department of Public Health has intrusted to Dr. Alfons Dampf, chief entomologist and head of the department of research in the Mexican Department of Agriculture, the study of the blood-sucking flies and other insects in the regions of the State of Guerrero where the "Mal del Pinto" exists. The etiology of this skin disease is absolutely unknown. As the chief centers of infestation are always near a watercourse, there is a slight probability that the transmitter may be a dipterous insect with an aquatic larva. Dr. Dampf's first trip to Guerrero was made in the month of December; the next will be made in March.

At the instance of the research coordination subcommittee of the British Committee of Civil Research, the forestry commissioners have constituted an Advisory Committee on Forestry Research. The members of the committee are as follows: Mr. R. L. Robinson (vice-chairman of the Forestry Commission), *chairman;* Dr. E. J. Butler (director, Imperial Bureau of Mycology); Dr. A. W. Hill (director, Royal Botanic Gardens); Dr. A. S. Joseph (director, Bureau of Soils); Dr. Guy Marshall (director, Imperial Bureau of Entomology); R. S. Pearson (director, Forest Products Research Laboratory); Professor R. S. Troup (director, Imperial Forestry Institute); Professor Wright-Smith (director, Royal Botanic Garden, Edinburgh); *secretary,* Mr. W. H. Guillebaud.

Dr. C. W. Edwards, professor of physics in Duke University, writer and lecturer on physics, on the occasion of the annual meeting of Sigma Pi Sigma, spoke at Davidson College, North Carolina, on "Properties of Matter at Very Low Temperatures."

Professor A. V. Hill will give a course of four public lectures at the University of London on oxygen and the recovery process in muscle and nerve beginning on January 20, and continuing on January 27 and February 3 and 10. A course of four public lectures on the chemistry of muscle in relation to problems of cellular physiology will be given at the university by Professor Otto Meyerhof, director of the Institute of Physiology of the Kaiser-Wilhelm Institut, Berlin, on March 6, 7, 10 and 12.

Dr. William Bosworth Castle in physiology and Dr. Frank Roberts Ober in orthopedic surgery have been promoted to assistant professorships in the Harvard Medical School.

Dr. Ch. Terzaghi, of the Massachusetts Institute of Technology, has been offered the professorship of hydraulics at the Technical Institute in Vienna.

Dr. R. J. Brocklehurst, lecturer in University College, has been appointed to the chair of physiology in the University of Bristol.

Terrestrial Magnetism reports that Dr. F. Lindholm, first Swedish state meteorologist, who was released by his government in 1926 that he might assume the directorship of the Physikalisch-Meteorologisches Observatorium Davos, founded by Dr. C.

Dorno, has given up that post in order to resume his former position. He is succeeded in the directorship of the Davos Observatory by Dr. W. Mörikofer.

DR. WILLIAM A. ARCHER, plant pathologist, recently of the U. S. Department of Agriculture, Office of Plant Disease Survey, has resigned to accept the position of professor of plant pathology in the School of Agriculture and Veterinary Science at Medellin, Department of Antioquia, Colombia. Previous to his departmental service Dr. Archer was engaged in teaching and research work in biology at New Mexico State Agricultural College, the University of Michigan and Oberlin College. He began his new work in South America on January 15. Mr. Charles H. Ballou, recently technical assistant in the U. S. Department of Agriculture Japanese Beetle Control Laboratory at Moorestown, New Jersey, has also gone to Medellin, to take the position of professor of entomology. Mr. Ballou is a graduate of Cornell University and has spent the past several years in entomological research in the tropics, particularly in Cuba. The appointments of Dr. Archer and Mr. Ballou were arranged through the Tropical Plant Research Foundation of Washington.

DR. LINSLY R. WILLIAMS, chief deputy of the late Dr. Hermann Biggs when the latter was New York State Health Commissioner under Governor Smith, has been offered the position of head of the State Health Department to succeed Dr. Matthias Nicoll, Jr., who recently retired to take up health work for Westchester county.

R. V. MCGREW, formerly of the University of Nebraska, Northwestern University and Harvard University, now a research chemist with the Rohm and Haas Company, has been transferred from their Philadelphia laboratory to the Pennsylvania State College.

ASSOCIATE PROFESSOR HERBERT W. RAND, of the department of zoology of Harvard University, will be on leave of absence during the second half of the current academic year.

THE afternoon lectures at the Royal Institution, London, were resumed on January 21, when Dr. F. W. Aston began a course of three lectures on Tuesday afternoons on "Isotopes"; on succeeding Tuesdays there will be four lectures by Sir William Bragg on "X-Ray Determination of the Structure of Cellulose and Similar Substances," and four by Dr. Charles Singer on "The Passage from Mediaeval to Modern Science." On Thursday afternoons, beginning on January 23, were two lectures by Dr. H. A. Harris on "The Growth of Children in Health and Disease," one on February 6 by Dr. R. L. Smith Rose, on "Radio Direction Finding by Transmission and Reception," and two by Mr. T. A. Joyce on "Architecture and the Industrial Arts of Pre-Spanish America." The Saturday afternoon lectures will include four by Sir Ernest Rutherford on "Atomic Nuclei and Their Structure." The first Friday evening discourse was given on January 24, when Sir William Bragg spoke on "Cellulose in the Light of the X-Rays." Succeeding discourses will probably be given by Lord Rayleigh, Dr. Leonard Hill, Professor A. F. Pollard, Professor G. I. Taylor, Mr. C. Tate Regan, Professor G. Elliot Smith, Mr. Seton Gordon, Sir Ernest Rutherford and others.

DR. LUDWIG PRANDTL, professor of physics, mechanics and thermodynamics, and director of the Kaiser Wilhelm Institute for Research in the Flow of Fluids at the University of Göttingen, will give two public lectures on the flow of gases and fluids at the Carnegie Institute of Technology. On the first night his subject will be "Flow of Gases at Velocities above Those of Sound," and on the second night he will speak on "Molecular Theory of the Elastic Hysteresis of Plastic Flow." The great aerodynamic laboratory which he directs is widely known. The wind-tunnel in this laboratory is being taken as a model throughout the world. The tunnel being constructed now at the Carnegie Institute of Technology is patterned after the Göttingen type. Dr. Prandtl comes to Pittsburgh from the University of Michigan where he has given a series of lectures. A dinner was given in his honor at the Faculty Club of the University of Pittsburgh.

THE Abraham Flexner Lectures for 1930–1931 will be delivered by Sir William Hardy, of the University of Cambridge. Sir William, who was knighted for contributions to science, has delivered the Croonian and Bakerian Lectures in England. He is a past secretary of the Royal Society, and now is conducting experiments on the cold storage and preservation of foods for the British Government. He is director of the Low Temperature Research Station of Biochemistry and Biophysics at Cambridge. The first series of the Flexner Lectures was delivered last year by Dr. Heinrich Pohl, director of the Anatomic Institute of Hamburg, Germany.

THE Second International Congress on Malaria will be held in Algiers, from May 19 to 21, 1930. Delegates of governments, of scientific institutions and societies and physicians who wish to attend the congress are requested to register their names as soon as possible with the Secrétariat-Général du deuxième Congrès internationale du Paludisme, Institut Pasteur, Algiers. French railways and steamship companies will accord favorable rates to those attending. The

secretary wants to know the numbers to be arranged for on ships in the Mediterranean and lodged in Algiers.

THE first International Anatomical Congress to be held since the war will meet at Amsterdam next summer from August 4 to 9.

THE Annual Congress on Medical Education, Medical Licensure and Hospitals will be held at the Palmer House, Chicago, February 17, 18 and 19, under the auspices of the Council on Medical Education and Hospitals of the American Medical Association.

ON January 14 there was held a meeting in the hall of the Franklin Institute, Philadelphia, to which were invited the advanced students in physics from Haverford, Swarthmore, Bryn Mawr and Villa Nova Colleges, the University of Pennsylvania, the Moore School of Engineering, Delaware and Temple Universities and Drexel Institute. The meeting was addressed by Dr. Herbert E. Ives, of the Bell Laboratories, New York City, on "Physics and a Large Industrial Organization," and by Professor Karl T. Compton, of Princeton University, on "Physics and a Large University." It is proposed to hold further meetings at which other opportunities open to students of physics will be discussed.

THE third annual conference of workers with the *Phymatotrichum omnivorum* root-rot of cotton and other plants was held on January 15 at the Kyle Hotel, Temple, Texas. A. B. Conner, director of the Texas Agricultural Experiment Station, presided at the morning session, and Dr. A. G. McCall, chief of soils investigations of the U. S. Department of Agriculture, Bureau of Chemistry and Soils, at the afternoon session. On January 16, the scientists and others at the conference visited the Blackland Substation, near Temple, of the Texas Experiment Station system. Forty papers were presented, giving the results of work during the past year at the various state and federal stations where the disease is under investigation. These papers will be summarized in a forthcoming report in *Phytopathology*.

Museum News reports that the British Museums Association has organized a permanent staff and established headquarters at 39 Alfred Place, opposite South Kensington Station, London. Sydney Frank Markham, M.P., has been appointed by the executive committee as permanent secretary and Miss Vera Cummings as full-time assistant to Mr. Markham. At the unanimous request of the committee Sir Henry Miers has accepted reelection to the presidency for the year 1930–31. Mr. Markham plans to compile a directory of museums to include all institutions in the British Dominions. The establishment of a permanent organization is made possible by a grant of £1,500 from the Carnegie United Kingdom Trust. The next annual conference of the association will be held in Cardiff, from June 23 to 27.

THE Rockefeller Foundation at the meeting of its Board of Directors last month appropriated the sum of $155,000 a year for two years beginning with the summer of 1930 to continue the support of post-doctorate fellowships in physics, chemistry and mathematics with the understanding that approximately $125,000 of this sum will be expended for the support of American fellows in the United States and about $30,000 for the support of American fellows abroad. At the same time the Rockefeller Foundation appropriated the sum of $20,000 a year for two years beginning next summer for the support of American fellows in the biological sciences who wish to work abroad.

THROUGH the courtesy of the U. S. Government Bureau of Mines, the Canadian Department of Mines, Ottawa, has received the following motion picture films for free circulation throughout Canada: "The Story of Sulphur" (2 reels); "The Story of Rock Drilling" (2 reels); "The Story of Steel" (6 reels); "The Story of Gasoline" (3 reels); "Heat Treatment of Steel" (2 reels); "Through Oil Lands of Europe and Africa" (2 reels); "The Story of Dynamite" (2 reels), and "Carbon Monoxide: The Unseen Danger" (1 reel). All these films are on standard (35 mm) stock, and all are non-inflammable except "The Story of Rock Drilling." No charge is made for the rental of the films, but the borrower is expected to pay express charges.

A CORRESPONDENT writes: "The indefatigable Chilean naturalist, Dr. Carlos E. Porter, of Santiago, Chile, has announced the coming publication of a very large work entitled (translated) "Historical Review and Bibliography of Natural Science in Chile." He is compiling under this title a work to be issued in eighteen volumes. These will contain brief biographies of a large number of prominent men in the field of natural sciences, with their portraits, and over fifteen thousand bibliographic references relating to the anthropology, fauna, flora, geology, paleontology and mineralogy of Chile. They will contain also an abridged statement on all the biological work concerning applied zoology and botany as well as agriculture, medical science and veterinary science. After the publication of all the eighteen volumes, supplementary volumes will be issued at intervals of four years. The work of South American naturalists is not as well known in the United States as it should be, and there can be no doubt that this great work will be of much assistance to all naturalists.

APPLICATIONS for the Eastern fellowship in analyti-

cal chemistry provided by the J. T. Baker Chemical Company, which is of the value of $1,000, should be made before February 13. The fellowship is available for students in any institution conferring the doctor's degree in chemistry in the New England States, New York, Pennsylvania, New Jersey, Delaware and Maryland. The committee on award is as follows: N. H. Furman, Princeton University, chairman; Gregory P. Baxter, Harvard University; Philip E. Browning, Yale University, secretary; E. M. Chamot, Cornell University, and H. A. Fales, Columbia University. The Mid-Western Fellowship will be available for students in any institution conferring the doctor's degree in chemistry in Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio and Wisconsin. Applications may be sent by any member of the teaching staff who is qualified to supervise a doctor's dissertation. Further information may be secured from the committee: H. H. Willard, University of Michigan, Chairman; C. W. Foulk, Ohio State University; Stephen Popoff, Iowa State University; G. F. Smith, University of Illinois.

DISCUSSION

THE CENTRAL ASIATIC EXPEDITION

WE have been sorry for controversy which arose from the case of the Central Asiatic Expedition led by Dr. Roy Chapman Andrews, and the interpretation given to this by Dr. Henry Fairfield Osborn as he wrote it in the September 27 issue of SCIENCE. We shall be much obliged if you can publish this letter and the accompanying statement for the information of American scientific public.

The meaning and the reason of the proposed agreement (text already reported by Dr. Andrews) put forward by the Chinese committee are already explained in our statement of April 19, and need not be repeated. Certain restriction of extensive collection by foreign expeditions and of the export of large amounts of scientific material is not without precedent in scientific world, and does not mean anti-foreignism. The opinion of the Chinese committee is that such large expeditions should be allowed only on the condition of a close cooperation with Chinese scientific bodies and the retention of complete representative collection in China. Such has been the principle in the committee's action dealing with all other foreign expeditions, while Dr. Andrews has tried to avoid Chinese participation before the autumn of 1928 and always to obtain unconditional authorization.

The committee is always ready to consider any practical proposal toward the solution of the problem and regrets to see the exaggerated meaning purposely given to the incident in order to disturb American opinion. It is hoped that Dr. Osborn, well known for his broad mind and sane judgment, and other American scientists will find no difficulty in understanding the true Chinese attitude.

The statement follows:

Public opinion in China was aroused against the export of a large amount of important scientific material by the Central Asiatic Expedition from Chinese territory without any Chinese control or participation in preceding years. The case is the more surprising that such extensive excavations were done under the cover of a passport for hunting only. Some negotiations took place and an agreement was reached in October, 1928, between this committee and Dr. Andrews, the leader of the Central Asiatic Expedition, providing certain conditions for the return of duplicate specimens and casts and the possibility of organizing future expeditions under new conditions of cooperation to be agreed upon.

At the beginning of February, 1929, Dr. Granger on behalf of the Central Expedition in a letter approached this committee for permission to launch a new paleontological expedition to Inner Mongolia and proposed on his own initiative (1) to take two Chinese scientists on the expedition and (2) to return after study a complete set of duplicate specimens or casts of vertebrate fossils.

These proposals were carefully considered by this committee in a full sitting of all its members present in Peking together with the members of the Peiping local committee. It was then decided that a draft agreement be made which, while giving full consideration to the scientific interest of the expedition, tries to provide for necessary safeguards of Chinese interest and cooperation in this important scientific enterprise.

The full text of the proposed agreement is herewith appended. From the Chinese point of view a complete set of the fossils collected including unique specimens should be kept in or returned to China after study. But in view of the large expenses borne by the expedition and the scientific interest of the American Museum of Natural History in having representative specimens kept in New York, the proposed agreement is so worded as to still make possible the transport of the bulk of the collection to America for scientific study on the condition that representative duplicates of each species shall be returned to China which together with the casts (of those specimens which have no duplicates) will constitute a complete representation in China of the whole fauna collected.

As it was admitted by both sides from the beginning that some Chinese paleontologist shall take part in the field work on one hand, and on the other hand the bulk of the collection should be scientifically studied and described in America, the difficulty was immediately felt that there would be no scientific interest for the Chinese specialist who would only help in the collection and have no opportunity of taking part in the real scientific work.

To remedy this difficulty, it was thought desirable that one Chinese specialist shall be offered the opportunity of going to the American Museum to describe a part of the material which he has helped to collect.

These proposed terms with the underlying ideas were put before the leaders of the Central Asiatic Expedition on March 26. These gentlemen, after some discussion and explanation, agreed in principle and went on discussing the details, in the subsequent two meetings, as to how many (two or three) Chinese representatives the expedition can take and how long (one or two years) would be necessary for the Chinese paleontologist to stay in America in order to accomplish some real work. The details of these questions were also mainly agreed upon and it was already understood that the expedition was making necessary preparations to leave, when Dr. Andrews, at the meeting of April 16 which was understood to be final, brought up the proposal that Article IV of Clause A (providing for the leaving in China of specimens which can be readily recognized as duplicates without special study) should be entirely omitted unless an additional clause be inserted that Dr. Granger is to be the only judge of what is duplicate or not. In an extremely conciliatory spirit, the representatives of the committee assured Dr. Andrews that the committee already admits the necessity of studying most of the specimens in America; that the scientific authority of Dr. Granger in this matter is unquestioned by the Chinese committee, and in any unlikely case of divergence of views full consideration will be paid to his opinion. But they felt it beyond their power to accept any insertion which will admit absolutely no saying from Chinese side although they were quite willing to consider any other wording. On this point Dr. Andrews refused further discussion.

The committee was surprised to read the news in Wednesday's newspapers evidently given out from Andrews which is in many points contrary to facts. The committee has fully considered the scientific interest of the American Museum; there was never question of paying as many as three Chinese scientists in America, and there was absolutely no new demand besides the agreement provisionally reached a fortnight ago. The committee can not but feel sorry for the deadlock of the negotiations for which only the unexplainable sudden change of Dr. Andrews' attitude is responsible and the utter distortion of facts in his news communication which will not contribute to mutual good feeling.

SIN PINGCH'ANG,
General Secretary
For the Chinese Committee of the Preservation of Archeological Objects

THE NATIONAL INSTITUTE OF PSYCHOLOGY

THE National Institute of Psychology was incorporated in the District of Columbia on June 29, 1929, by Hugh S. Cumming, E. E. Slosson and Knight Dunlap. The steps which led up to this incorporation were initiated by the Conference on Experimental Psychology, held at Carlisle, Pennsylvania, under the auspices of the division of anthropology and psychology of the National Research Council, and composed of representatives of the principal psychological laboratories in the United States, which included among its final recommendations the following:

Be it resolved: That the Conference on Experimental Psychology of the National Research Council approve in principle the establishment of a National Laboratory of Experimental Psychology, and the establishment of further Institutes of Psychology connected with universities.

To this end, be it further resolved, that this conference recommends that a Committee on Experimental Psychology be set up in the Division of Anthropology and Psychology of the National Research Council to promote intensive and continuous research on fundamental problems.

It shall be the duty of this committee:

1. To formulate plans and to seek financial support for a National Laboratory of Experimental Psychology on a scale adequate for attacking fundamental problems of psychology calling for extensive equipment and special technique.

2. To support the efforts of universities to establish research institutes of psychology, each of which may be expected to study one of the fundamental problems of experimental psychology.

3. To consider any other means for the promotion of psychological research.

This resolution was duly presented to the division at its annual meeting on April 21, 1928, and approved by the following actions:

Voted: That the chairman of the division recommend the appointment of a Committee on Experimental Psychology under the division.

Voted: That the recommendation of the Carlisle Conference, looking toward the establishment of a National Laboratory of Psychology, preferably in the District of Columbia, and the furthering of psychological institutes under the auspices of the universities be approved.

The first of these two votes was in accordance with the usual procedure by which the establishment of new committees is recommended by the chairman of the division to the executive board or the interim committee of the council. It was understood by the division that while the National Research Council might be willing to hold funds temporarily for the laboratory, it could not, in consistency with its general policy, undertake the organization or control of any such laboratory.

The committee on experimental psychology was duly established, its members being Madison Bentley,

Harvey A. Carr, Knight Dunlap, Samuel W. Fernberger and F. Lyman Wells. At a meeting held on April 11, 1929, the committee agreed upon the organization and incorporation of a National Institute of Psychology as a controlling body for the projected National Laboratory.

This action was reported to the annual meeting of the division on April 12, 1929, but no further action was requested from the division, since it seemed that the division had gone as far as it could officially go in endorsing the project.

The details of incorporation were left by the committee to the chairman of the division, the committee itself being precluded from acting as incorporators by the requirement of the District of Columbia that the majority of incorporators must be residents of the district. The committee prepared for the incorporators an initial list of members and cooperated with the chairman and the legal adviser in drawing up a set of by-laws for the institute.

The incorporators met on August 30, in Washington, elected the initial list of members which had been prepared by the committee, elected a board of directors, consisting of the members of the committee on experimental psychology, with a president and secretary to serve until the organization of the board, and adopted the by-laws which in principle and in most details had been approved by the committee. The incorporators thereby relinquished their control over the corporation.

The directors met at New Haven on September 4, 1929, and elected officers as follows: *President,* Knight Dunlap; *vice-president,* F. Lyman Wells; *secretary and treasurer,* S. W. Fernberger. These with Madison Bentley and Harvey A. Carr are the board of directors.

The essential provisions of the by-laws (which may be modified after one year) are as follows:

1. Active membership is restricted to fifty, who shall be qualified by research in experimental psychology.
2. Members beyond the initial group elected by the incorporators must be nominated by 80 per cent. affirmative vote of the active members, and elected by the directors.
3. Members reaching 60 years of age cease to be active, and become honorary members. Other honorary members may be elected by the same procedure as that for the election of active members.
4. Active members who fail to publish significant research within a certain period of time become associate members.

These provisions are somewhat drastic, and are frankly experimental. It is easy to widen qualifications for membership, extend age and number limits and otherwise lessen restrictions when such lessening is clearly advisable. The opposite procedure, however, is much more difficult, and the committee desired to be on the safe side.

It should be said that before setting the numerical limit of 50 (which includes associates, but not honorary members), the committee canvassed the list of American psychologists, and taking into account the ages of the initial group of members and their dates of elevation to honorary membership, saw no prospect of the membership of 50 being filled for many years. The nominating requirement of 80 per cent. affirmative vote of the members may be too high: that point can be determined in practice.

The authority of the directors, as granted by the articles of incorporation, is high and may be said to be autocratic. This feature is the result of competent legal advice, which has pointed out that no corporation otherwise constituted could command financial confidence, or be able to function adequately in case of war or other emergency. It is clear, however, that the affairs of the institute are really in the hands of the membership as soon as the members are organized, and no directorate would be able to maintain a policy opposed to the will of the membership. The institute, in short, is republican, so that the members are guaranteed the continual dignity and responsibility of the institute and satisfactory guardianship of its property and policies.

The ultimate plan of the directors of the institute, subject to approval by the membership, is the establishment of a laboratory either in the District of Columbia or immediately adjacent thereto, in which there shall be provision for a permanent staff and adequate equipment for research in human and animal psychology. It is deemed possible through such provision not only to undertake the solution of problems too large in time and equipment required to be handled by university laboratories, but also to foster the development of a real comparative psychology. Provision for temporary staff appointments are also contemplated, so that integration with other laboratories will be promoted, and individuals can be offered opportunities to complete at the National Laboratory research which has been begun elsewhere. If, eventually, temporary appointments from abroad can be provided, the institute should become maximally efficient in the promotion of research in the United States. The institute is legally empowered to advance scientific work in psychology by publication and all other appropriate means.

KNIGHT DUNLAP

THE BRIGHT METEOR OF JANUARY 3, 1930

AT approximately 5:50 A. M., Eastern Standard Time, on January 3, a brilliant meteor or fireball

flashed across southern Ontario and northern Ohio, and possibly regions farther south. It was seen by the writer from Ann Arbor, Michigan, and was reported from Cleveland as having been seen in western Pennsylvania. It left a reddish train, parts of which were visible for some seconds. The brilliancy of the meteor lasted perhaps three seconds as seen by the writer, and was equal to that of a very bright flash of lightning, the surrounding landscape being strongly illuminated. The writer did not see the entire path, because a building obstructed the view. An observer in Detroit states that the meteor burst into a number of fragments. His data, coupled with the writer's observations, would appear to indicate that the burst occurred over central or southern Ohio.

The writer is desirous of obtaining as much information as possible concerning this body. Such data should include the altitude and azimuth of the point of burst or of the mid-point or ends of the luminous train or all these, if possible. The apparent angle between the path or train and the vertical should be given. The best kind of observation would be a plot of the apparent path of the meteor relative to identifiable stars. Even rough values, if obtained at points one hundred miles or more from Ann Arbor, would be of value, and observations of the meteor passing directly overhead, or nearly so, are also desirable. It is evident that a person need not know even the barest rudiments of astronomy in order to furnish some of the data mentioned. Undoubtedly many who saw it have refrained from giving any notice of it because they feel that their observations would be of no value.

If the observer recalls the place where he stood when the meteor was seen and remembers the relation of its path to the neighboring terrestrial objects, he may be able to determine fairly reliable data by going again to the point of observation with a transit or clinometer and compass, or even with no instruments at all except his eyes and a little good judgment. From some localities even the bare statement that the meteor was seen to burst in the northern sky would be of value, since it would set a limit to its flight.

If enough information can be obtained it should be possible to calculate the orbit of the meteor, both relative to the earth and to the sun. The point of burst especially should be well determined, and it might be possible to indicate within rather close limits the area within which fragments might be found.

DEAN B. MCLAUGHLIN
DETROIT OBSERVATORY,
ANN ARBOR, MICHIGAN

SYNCHRONOUS FLASHING OF FIREFLIES

SYNCHRONOUS flashing of fireflies is noted in the Philippines December 6, and with the seven preceding notes published in SCIENCE since E. S. Morse raised the question February 4, 1916, the phenomenon has been frequently recorded. Since none of these references mention Mexico I call attention to Terry's Guide, page 568:

"A singularly beautiful insect is found in and near the Palonque ruins." Then follows a quotation from early Spanish chroniclers and statements: "This insect, which is common to the tropical forests bordering the Gulf of Mexico, belongs to a family of beetles known as the Elateridae, and is called by the Indians cucuji. . . . The insects congregate by the thousands on certain forest trees, and as if at a given signal simultaneously flash their lights; then darken them and flash them again," etc.

R. H. MERRILL

BUSUANGA HERRE, NEW GENUS

THIS genus is distinguished from other genera of the Belonidae by the anterior extremity of the mandible, which extends beyond the snout and terminates in a thick, spongy, somewhat flexible tip, much thicker than the rest of the mandible and forming a continuation of the upper profile of the beak.

The type is *Busuanga philippina* Herre. It has been described and figured as *Tylosurus philippinus* Herre, in *Philippine Journal of Science* 35 (1928), 31, plate 2, and in *Philippine Journal of Science* 36 (1928), 228, plate 3.

Busuanga, from the island where the fish was first found. Busuanga is one of the Calamianes, an island group in the Philippines between the Sulu and China Seas.

ALBERT W. HERRE
ZOOLOGY MUSEUM,
STANFORD UNIVERSITY

SCIENTIFIC BOOKS

The Problem of Krakatoa as Seen by a Botanist. By C. A. BACKER, formerly government botanist for the flora of Java. For sale by Martinus Nijhoff, The Hague. 18 by 26 cm. 299 pp.

THE volcanic island Krakatoa, devastated in 1883 by a terrific eruption, has greatly interested botanists ever since Treub published his observations on revegetation. This universal interest was due to the fact that it was considered certain that the original flora and fauna had been wholly destroyed by the eruption.

Hence it was considered that Krakatoa presented an exceedingly rare opportunity for tracing the colonization of new soil by living beings.

Backer, who has been interested in the problem for many years, having studied the new vegetation on the spot as long ago as 1908, now comes forward with a critical review of all the work that has been done on the "new" flora.

As, unfortunately, so often happens in the progress of science, Backer now finds that the observations of the first years upon which all subsequent work must be predicated were neither exact enough nor extended enough to support the conclusions that have been built upon them. Treub and the other early workers apparently assumed, without considering it necessary to examine thoroughly, that so violent an eruption must necessarily have destroyed all vegetation and left the island sterile throughout. Certainly they did not explore all parts of the island or even representative habitats of all sorts but confined their attention to relatively small areas in the lowland. And certainly they did not submit any detailed data supporting their assertions of complete sterilization.

Backer now points out a number of circumstances which make it seem probable that the new vegetation consisted largely of holdovers rather than entirely of immigrants.

His reasons for this conclusion are three:

(1) The hot ejecta never accumulated on the steeper parts of the island but rolled off to the flats leaving the slopes relatively little injured.

(2) Plants large enough to be observed from the deck of a ship were seen on the slopes within three years after the eruption. (These were not examined close up and it was many years before the volcano was actually ascended.)

(3) While the flora of the strand demonstrably consisted of water-borne pioneers, the flora of the heights was of very different complexion. No careful studies have ever been made to determine its origin.

The ferns which played an important part in the colonization of the lowland back of the strand may, Backer thinks, quite as likely have come from adjacent cliffs as from a distance.

As to the probable weight of Backer's criticism the reviewer may add that his own experience at Katmai showed that the most careful investigation is necessary before it may be safely concluded that a volcanic territory has been completely sterilized. In Katmai Valley abundant plants of many species came up from old roots in places which had been buried under several feet of ash for three years and were later cleared by flood waters. One such habitat was found well up the slopes of the volcano and others at its foot. Certainly we would not have believed it possible for plants to survive under such conditions if we had not demonstrated it. In view of the similarity in character of the two eruptions it would seem likely that plants also survived here and there on Krakatoa.

As a result of his critique Backer concludes:

(1) It is not at all proved that by the eruption of 1883 all vegetable life on Krakatoa was destroyed.

(2) Even if this could be proved, we know—with the exception of the littoral flora—nothing at all about the manner in which the new vegetation has appeared. Only guesses without scientific value have been made but no reliable observations or experiments.

(3) Therefore, the Krakatoa problem can neither now nor in the future either be proved or solved and is of no importance at all for botanical science.

ROBERT F. GRIGGS
THE GEORGE WASHINGTON UNIVERSITY

Die Biologie der Moore. By O. HARNISCH. Bd. VII of Thienemann's Binnengewässer, 1929, 146 pp., 3 pl., 30 figs. Published by E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.

A MOOR is defined as a continuous tract of land from whose moisture-loving plants there is forming (a living moor) or has formed (a dead moor), under the influence of terrestrial or telluric water, a massive accumulation of decomposition products rich in carbon. European moors have been studied extensively during the past two decades, and a considerable volume of literature dealing with this field of science has been published. The present volume gives a good résumé of the more important results contained in these publications. The ecological phases of the subject are especially emphasized.

Moors are discussed under two general heads, (1) as habitats and (2) the plant and animal societies that are found therein. The character of a moor as a habitat is determined largely by the character of the water supply; that is, whether the water holds a large or a small amount of mineral salts in solution which will serve as plant food material. The quantity of salts, in turn, is dependent upon the character of the rocks with which the water has come into contact. The amount of salts also determines whether the moor is eutrophic or oligotrophic. The abundance of the water supply, the temperature, the light intensity and the hydrogen-ion concentration are important factors also. By means of the method of pollen analysis the history of a moor from the time of its formation to its present stage may be ascertained.

Under life societies, the author takes up first the life of the ponds and pools that occur in moors. The algae, protozoa, rotifers and crustacea of the open waters are considered as well as the bottom fauna. The population is made up of ubiquitous forms and of those that are rather closely restricted to habitats of this character.

The moss turf usually holds a great deal of water which is well populated with a great variety of characteristic forms of algae, rhizopods, Turbellaria, rotifers and nematodes. In high moors the population is much smaller and the variety of organisms is rather limited. There is also a characteristic air-breathing fauna which shows considerable variation in composition in the different kinds of moors.

A bibliography of 178 titles is given.

C. JUDAY

WISCONSIN GEOLOGICAL AND NATURAL HISTORY SURVEY

Icones Plantarum Sinicarum. By H. H. HU and W. Y. CHUN. Fasc. 2, pp. 1–50, pl. 51–100. The Commercial Press, Shanghai, 1929.

THIS folio work prepared under the auspices of the Science Society of China and the department of botany, National Central University, Nanking, reflects distinct credit on both the authors and the publishers. Detailed descriptions in both English and Chinese of fifty indigenous species, together with important synonyms, geographic distribution, etc., are given. The figures, drawn natural size with enlarged details of the essential parts, are well executed and graphically represent the several species, many of which are here figured for the first time. The work is one that should be consulted by all botanists interested in the Chinese flora and in the preparation of monographic treatises.

E. D. MERRILL

UNIVERSITY OF CALIFORNIA

SCIENTIFIC APPARATUS AND LABORATORY METHODS

CHART ILLUSTRATING THE HISTORY OF BIOCHEMISTRY AND PHYSIOLOGY

MAY I be permitted to call the attention of the readers of SCIENCE to a recently published chart dealing with the history of the twin sciences of physiology and biochemistry?

This chart, which has been reproduced from the original by a lithographic process, gives a two-dimensional account of the historical development of these and cognate sciences. The arrangement is that of a graph, the vertical scale being in years and running from 1450 to 1900 with ten-year intervals marked off by horizontal lines. The lives of individual investigators are represented by continuous vertical lines beginning at the date of birth and ending at the date of death. Beside each such line is the name of the investigator in capital letters, with special signs indicating the university in which he was professor or the town where he worked. The vertical divisions group the investigators into anatomists, physiologists, biochemists, chemists, zoologists and philosophers. Diagonal wavy or dotted lines indicate relationships, controversies and succession in professorial chairs, and in this way also the main streams of intellectual influence are shown. At the date of publication of an important book or memoir, a thin horizontal line leaves the life-line of the investigator in question and leads to the title followed by a short description of the book. In addition to these descriptions there are quotations and notes interspersed throughout. In order to give an idea of contemporary events, the lives of men not biologists are shown in a separate column, *e.g.*, Galileo, Cervantes, Montaigne, Erasmus, Browne. Certain wars are also represented by vertical lines; the founding of associations such as the Royal Society is marked, and the beginnings of scientific journals noted. Before 1450 there is no regular time-scale, but the achievements of classical antiquity, the Hellenistic age and the dark ages are briefly referred to. The chart may be said to give a wide and detailed survey of the history of biochemistry and physiology, but its interest for biologists in general is considerable, as before 1800 the fields of study were not clearly differentiated, and until then the chart is practically a history of biology as a whole.

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FIXING THIN BLOOD SMEARS FOR STAINING WITH IRON HEMOTOXYLIN AND WITH GIEMSA'S STAIN

THE writer was unable to make satisfactory iron-hematoxylin preparations of blood smears that were fixed by the methods commonly in use because the erythrocytes retained this stain very tenaciously and, when they were finally destained, the chromatin of intracellular blood parasites was found to be likewise destained. The following modifications of well-known methods have, however, been made with success. Thin smears were dried in the same way as for Giemsa's preparations and fixation was completed by immersion in Schaudinn's alcoholic sublimate solution without acetic acid. The erythrocytes did not then take the hematoxylin, whereas the intracellular blood para-

sites stained well. In slides thus treated the cytological details of *Babesia bigemina* were brought out very clearly. Good results with iron-hematoxylin have also been obtained following wet fixation by formaldehyde. For this purpose the thin smears were dropped into a coplin staining jar that contained about 3 cc of 40 per cent. formalin and were then treated with alcoholic sublimate as for dried smears. The erythrocytes took the stain but were destained easily. It has been found difficult to make good dried smears of the blood of anemic cattle. This was especially the case when a high relative humidity retarded drying. The erythrocytes of such smears appeared full of air bubbles when examined under oil immersion. This difficulty has been overcome by the use of the wet formaldehyde fixation described above. Blood and blood parasites thus fixed stain well in Giemsa's.

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SPECIAL ARTICLES

A NEW BASIS FOR FERTILIZER EXPERIMENTS

EARLY in this century, Mitscherlich, the German experimenter of Königsberg, had discovered that the equation expressing the relation between yield of a crop and increase in the amount of a growth factor made available to the crop has the form

$$y = A(1-e^{-kx}) \qquad (1)$$

in which y is yield per acre, x is the quantity of the growth factor available, A is the maximum yield obtainable by the use of any amount of the factor and k is a constant.

Some years later, the writer, without knowledge of Mitscherlich's work—I was not then interested in this field of research—discovered that this law has the form

$$y = A(1-R^x) \qquad (2)$$

in which y, A and x have the same significance as in (1), while R is the ratio of a decreasing geometric series the terms of which are the increments of y corresponding to successive equal increments in x. I was also able to show that the e^{-k} of the Mitscherlich formula has the same significance as the R of my formula.

The German mathematician Baule pointed out, and Mitscherlich confirmed the same experimentally, that when two or more growth factors are varied simultaneously, this equation assumes the form

$$y = A(1-R_1^{x_1})\ (1-R_2^{x_2})\ (1-R_3^{x_3}) \qquad (3)$$

in which x_1 represents the quantity of the first growth factor, R_1 the ratio of the series of increments in yield due to increases in this factor; x_2 and R_2 have a similar relation to the second growth factor; x_3 and R_3 to the third, and so on.

Equation (3) applies to plants grown in water or sand cultures, in which the only amounts of the first, second, etc., factors available are those supplied by the experimenter, and which are therefore measurable directly. The purpose of the present preliminary note is to point out that in field experiments, on a soil containing n, p and k available units per acre of nitrogen, phosphoric acid and potash respectively, the above formula takes the form

$$y = A(1-R_1^{n+x_1})\ (1-R_2^{p+x_2})\ (1-R_3^{k+x_3}), \qquad (4)$$

and, further, to show how, with results from three fertilized plots, with suitable check plots, with sufficient replication to make the results reliable and with sufficient repetition from year to year to eliminate seasonal variations in yield, it is easily possible to calculate the values of the four constants A, n, p and k (the constants R_1, R_2 and R_3 are known from Mitscherlich's work) in equation (4), and then to use this equation for calculating the yield to be expected from the application of any quantities whatever of the three fertilizer ingredients, nitrogen, phosphoric acid and potash. The addition of other growth factors to the list requires only the addition of a single experimental plot for each factor, and, of course, the determination of the value of R for that factor. Mitscherlich has shown that the value of R is the same for all crops and all soils for a given growth factor when the unit of the growth factor is properly chosen.

The fertilizer treatment necessary on the four plots (three fertilized and one check plot) is shown in the following tabular statement:

	Units of fertilizer per acre			
	N	P_2O_5	K_2O	Yields
Plot 1.	a	0	0	y_1
" 2.	0	b	0	y_2
" 3.	0	0	c	y_3
" 4. (Check)	0	0	0	y_4

in which a, b and c are the respective amounts of nitrogen, phosphoric acid and potash, in units of 100 lbs. per acre, applied in fertilizer on the plots. The values of a, b and c should be such as to give considerable effect on yield so as to lessen the percentage

of experimental error, yet should not be so large as to cause the results to lie far out on the nearly horizontal portion of the yield curve. These quantities are best determined by preliminary tests with the growth factors in question.

The four observation equations which, by proper substitution in (4), these four experimental plots give are

$$\text{Plot 1. } y_1 = A(1-R_1^{n+a})(1-R_2^{p})(1-R_3^{k}) \quad (5)$$
$$\text{" 2. } y_2 = A(1-R_1^{n})(1-R_2^{p+b})(1-R_3^{k}) \quad (6)$$
$$\text{" 3. } y_2 = A(1-R_1^{n})(1-R_2^{p})(1-R_3^{k+c}) \quad (7)$$
$$\text{" 4. } y_4 = A(1-R_1^{n})(1-R_2^{p})(1-R_3^{k}) \quad (8)$$

Dividing (5) by (8)

$$\frac{y_1}{y_4} = \frac{1-R_1^{n+a}}{1-R_1^{n}}$$

From this equation the value of n is easily found.

In a similar manner the values of p and k are found. The value of A is then found by substitution of the known values of n, p and k in (8). Equation (4) is then available for calculating the yield to be expected from any amounts of nitrogen, phosphoric acid and potash applied as fertilizers.

This matter will be presented in detail in a paper soon to be offered for publication.

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THE EFFECT OF UNILATERAL SECTION OF THE MIDBRAIN UPON COSTAL MOVEMENTS OF RESPIRATION

I WISH to add to an earlier statement[1] some recent results of unilateral section of the midbrain combined with unilateral division of the dorsal roots of the thoracic spinal nerves.

Cats were used throughout the experiments. Respiratory movements were recorded by tambours attached to Crile stethographs. One stethograph placed well up on the chest measured costal movements; the other, at the level of the diaphragm, measured diaphragmatic movements.

Experimental procedures and results were as follows: (1) Section of the dorsal roots of the spinal nerves in the thoracic region of one side, followed by section behind the inferior colliculus of the opposite side. (2) Section behind the inferior colliculus of one side, followed by section of the dorsal roots of the spinal nerves of the opposite side. (3) Section of the dorsal roots of one side, and of the inferior colliculus of the *same* side.

(1) Unilateral section of the dorsal spinal nerve roots in the thoracic region produced some slowing of the respiratory rate and some diminution in amplitude of the costal respiration, but neither of these changes was as marked as when the dorsal roots of both sides were divided. Complete cessation of the costal movements was observed on the side on which section of the dorsal roots had been done. The movements of the other side were unchanged, but naturally the amplitude recorded was not as great as normal.

In doing unilateral section of the midbrain behind the inferior colliculus, the skull was trephined over the tentorium, and, guided by the tentorium, a knife was slid perpendicularly down its caudal surface, cutting the midbrain just below the inferior colliculus. Hemorrhage was controlled by means of bone wax. The extent and location of the lesion were determined at autopsy. The result of unilateral section was to slow somewhat the respiratory rate and, in some cases, to diminish costal respiration, particularly on the side of the lesion. Diaphragmatic respiration was adequately maintained at all times. Unilateral section of the midbrain below the inferior colliculus, then, appears not to interfere greatly with the respiratory rhythm.

When, however, section behind one inferior colliculus is followed by section of the dorsal roots of the thoracic nerves *on the opposite side,* costal respiration of both sides disappears, such slight excursions of the tambour lever as are shown being induced by the diaphragmatic contractions.

(2) When the procedures are reversed, the same result is obtained as in the preceding series. True costal respiration disappears.

(3) When both operations are done on the same side, costal respiration on that side only disappears.

These results appear to show that: (1) The central station in the midbrain for afferent respiratory impulses from the dorsal roots of the spinal nerves is ipsilateral. (2) Costal respiration only is affected by section of the dorsal spinal nerve roots, or by section behind the inferior colliculus.

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[1] F. H. Pike and H. C. Coombs, SCIENCE, 56: 691–692, 1922, and the papers there cited.

BOOKS RECEIVED

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